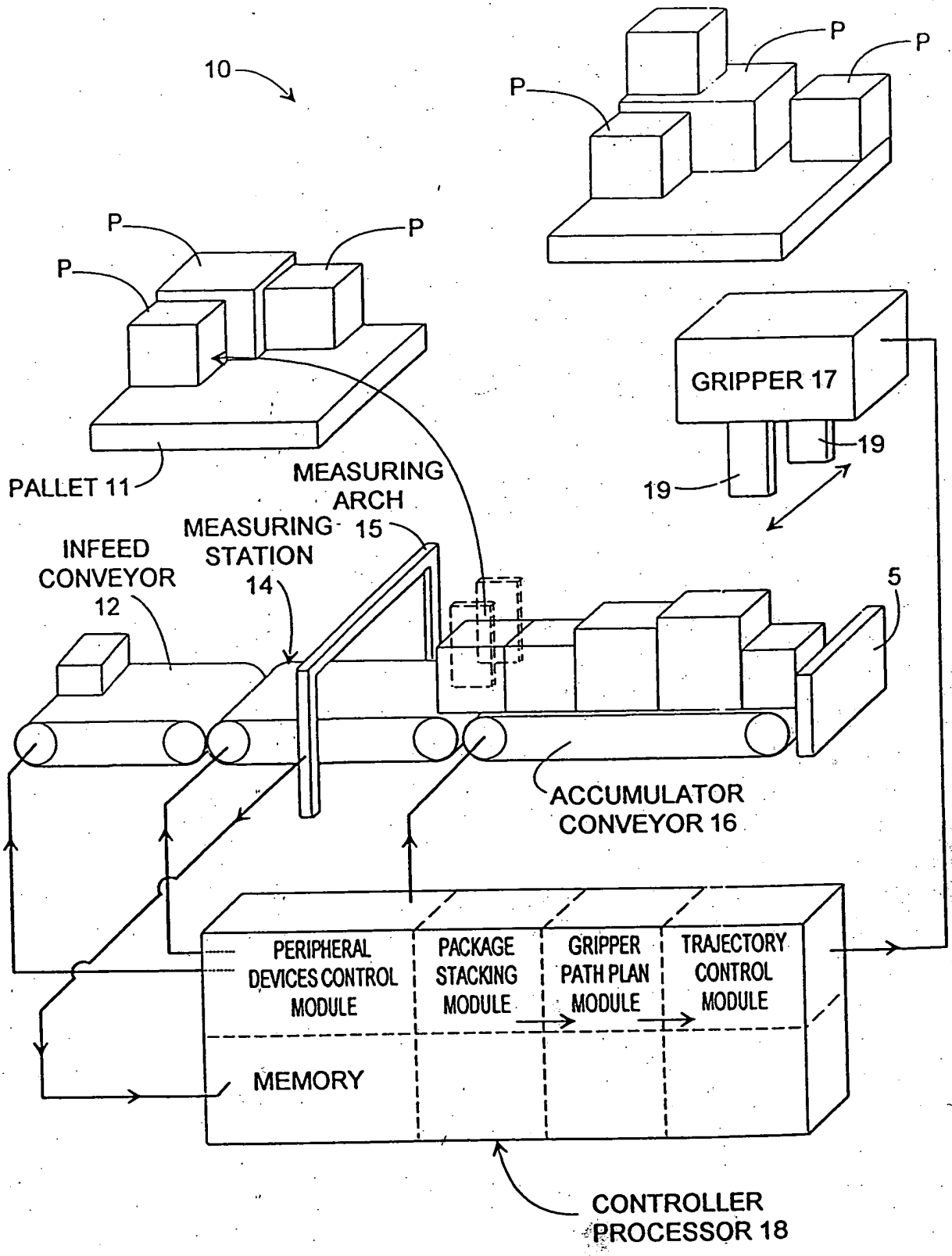

10
P
P
P
P
P
P
GRIPPER 17
19
19
PALLET 11
MEASURING ARCH 15
MEASURING STATION 14
INFEED CONVEYOR 12
5
ACCUMULATOR CONVEYOR 16
PERIPHERAL DEVICES CONTROL MODULE
PACKAGE STACKING MODULE
GRIPPER PATH PLAN MODULE
TRAJECTORY CONTROL MODULE
MEMORY
CONTROLLER PROCESSOR 18

FIG. 1

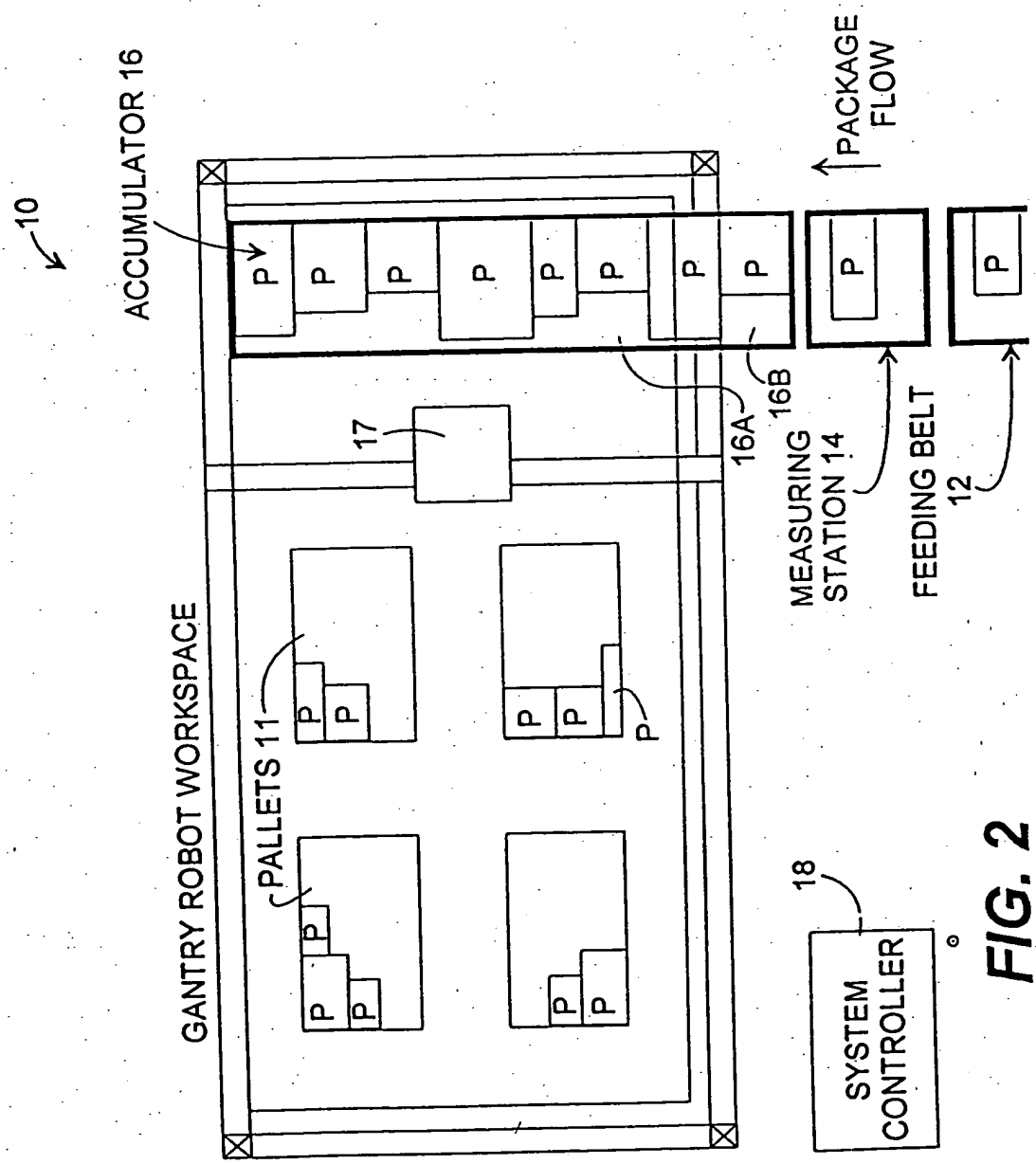

10
ACCUMULATOR 16
PACKAGE FLOW
P
GANTRY ROBOT WORKSPACE
PALLETS 11
17
16A
16B
MEASURING STATION 14
FEEDING BELT 12
18
SYSTEM CONTROLLER

FIG. 2

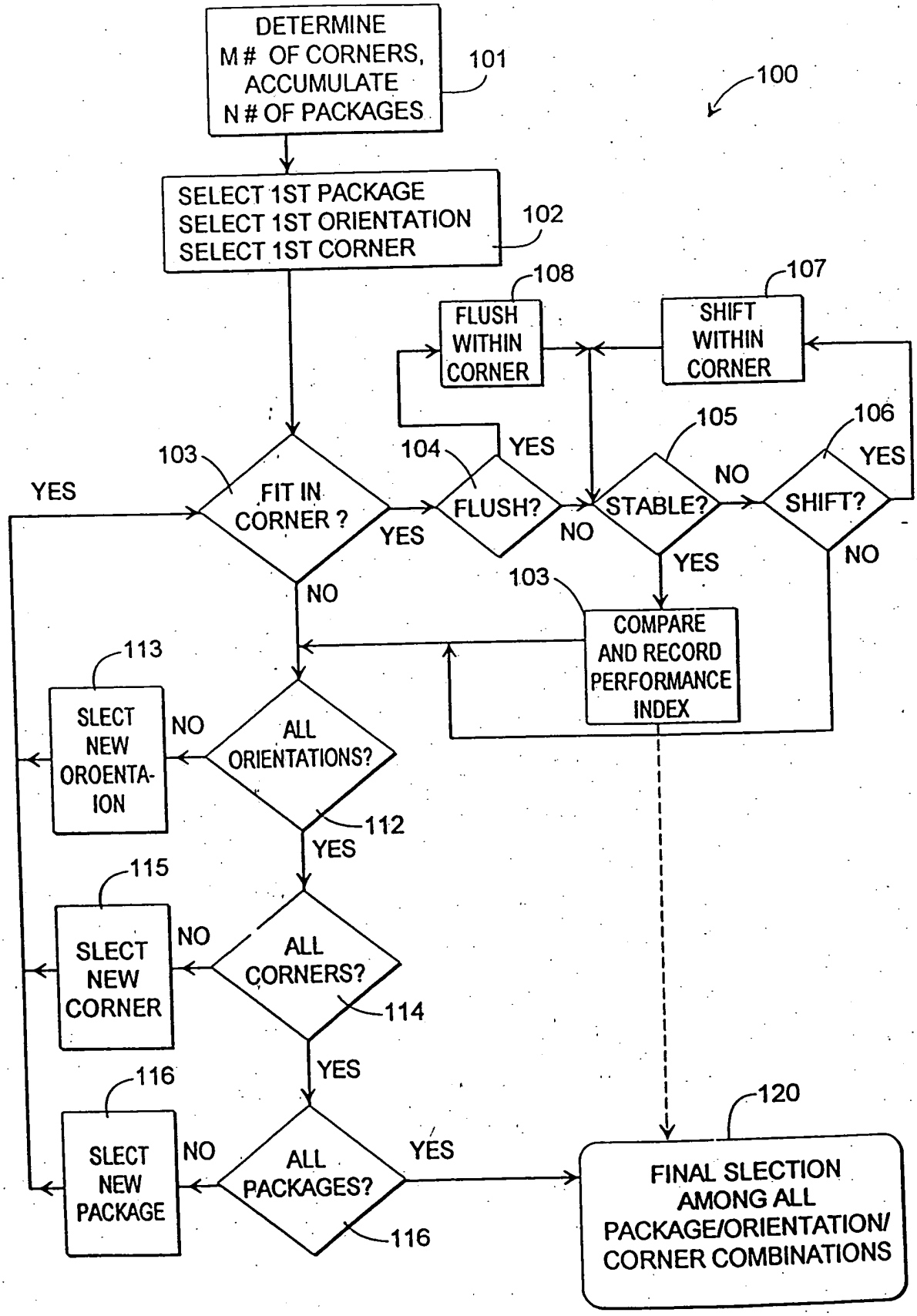

DETERMINE M# OF CORNERS, ACCUMULATE N# OF PACKAGES
101
100
SELECT 1ST PACKAGE
SELECT 1ST ORIENTATION
SELECT 1ST CORNER
102
FLUSH WITHIN CORNER
108
SHIFT WITHIN CORNER
107
103
FIT IN CORNER ?
104
FLUSH?
YES
105
STABLE?
106
SHIFT?
YES
NO
YES
NO
YES
NO
YES
NO
103
COMPARE AND RECORD PERFORMANCE INDEX
113
SLECT NEW OROENTA-ION
ALL ORIENTATIONS?
112
115
SLECT NEW CORNER
ALL CORNERS?
114
116
SLECT NEW PACKAGE
ALL PACKAGES?
116
120
FINAL SLECTION AMONG ALL PACKAGE/ORIENTATION/ CORNER COMBINATIONS

FIG. 3

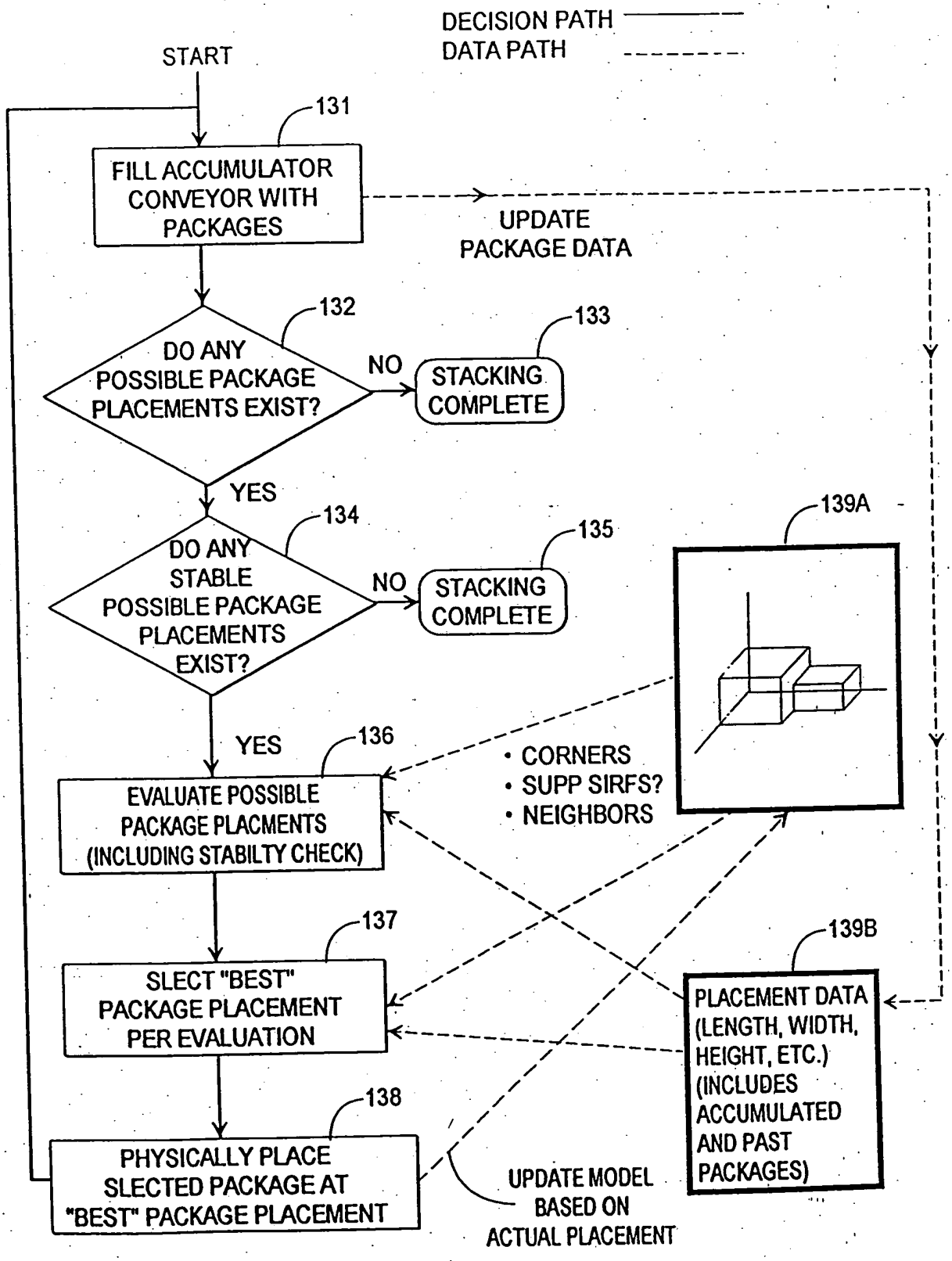

DECISION PATH
DATA PATH
START
131
FILL ACCUMULATOR CONVEYOR WITH PACKAGES
UPDATE PACKAGE DATA
132
DO ANY POSSIBLE PACKAGE PLACEMENTS EXIST?
NO
133
STACKING COMPLETE
YES
134
DO ANY STABLE POSSIBLE PACKAGE PLACEMENTS EXIST?
NO
135
STACKING COMPLETE
YES
139A
136
EVALUATE POSSIBLE PACKAGE PLACMENTS (INCLUDING STABILTY CHECK)
• CORNERS
• SUPP SIRFS?
• NEIGHBORS
137
SLECT "BEST" PACKAGE PLACEMENT PER EVALUATION
139B
PLACEMENT DATA (LENGTH, WIDTH, HEIGHT, ETC.) (INCLUDES ACCUMULATED AND PAST PACKAGES)
138
PHYSICALLY PLACE SLECTED PACKAGE AT "BEST" PACKAGE PLACEMENT
UPDATE MODEL BASED ON ACTUAL PLACEMENT

FIG. 4

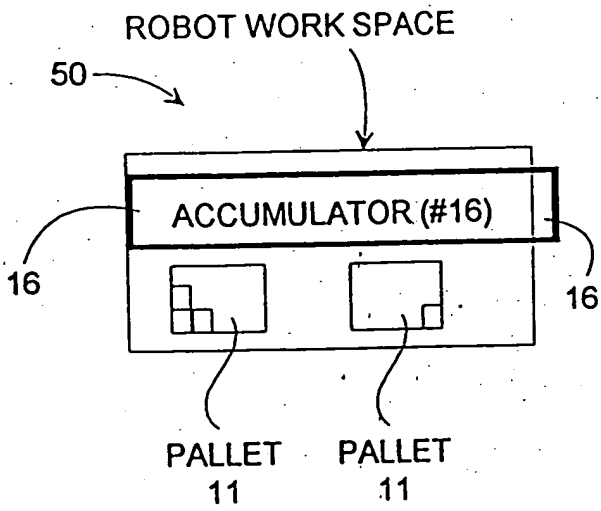


FIG. 5

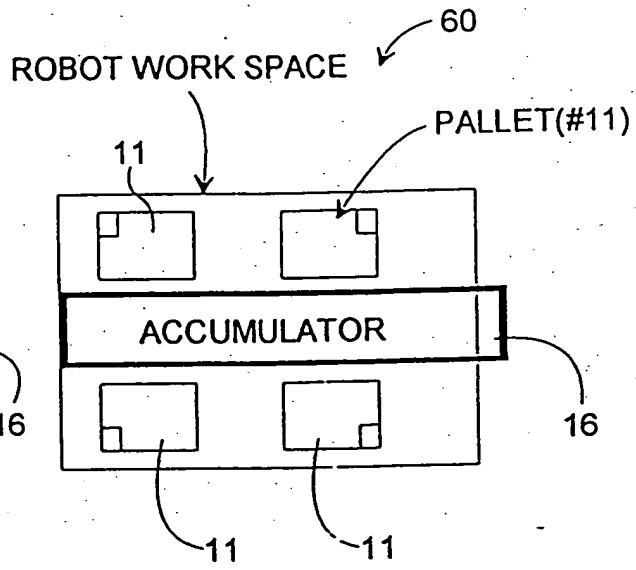


FIG. 6

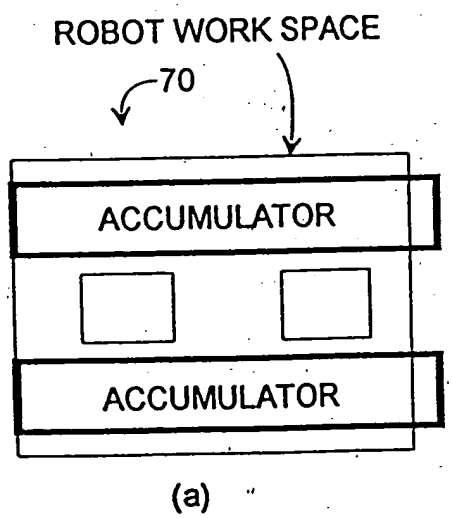


FIG. 7

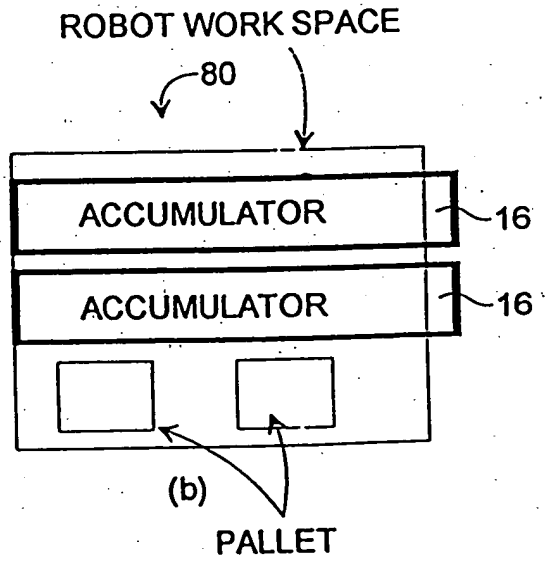


FIG. 8

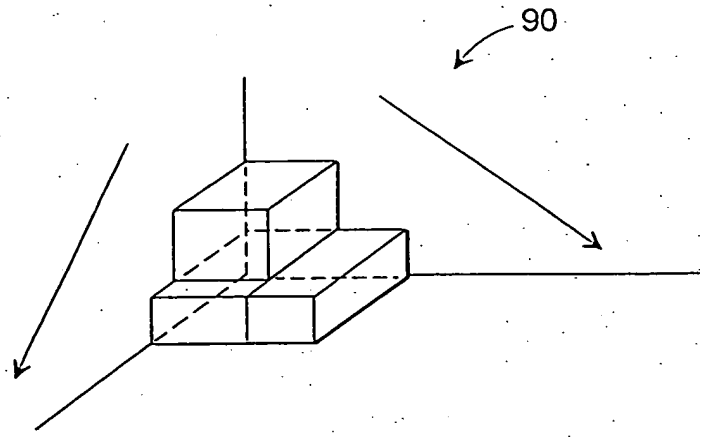

90

FIG. 9

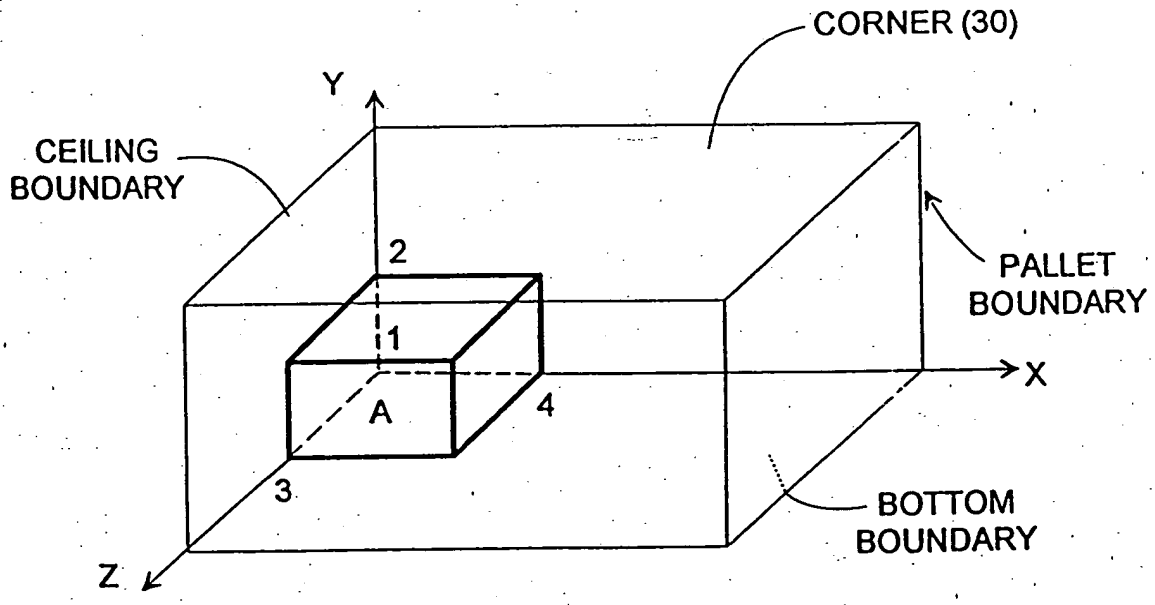
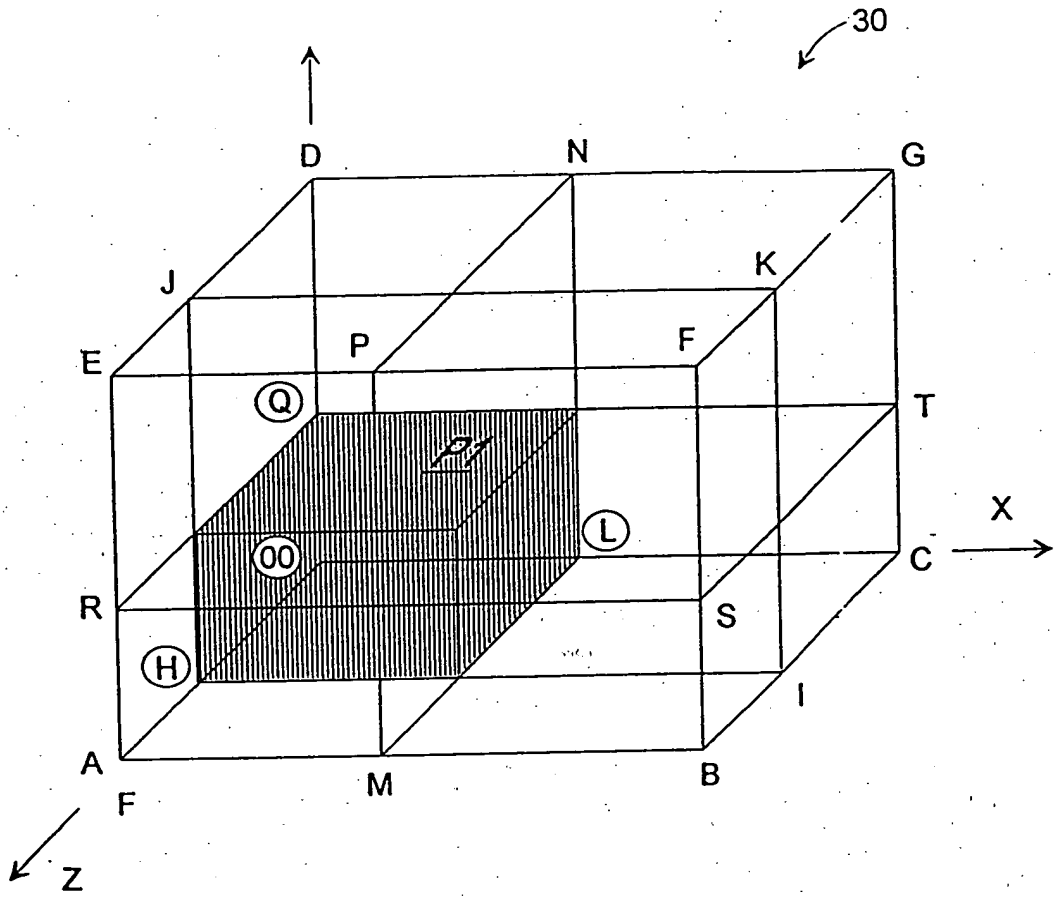
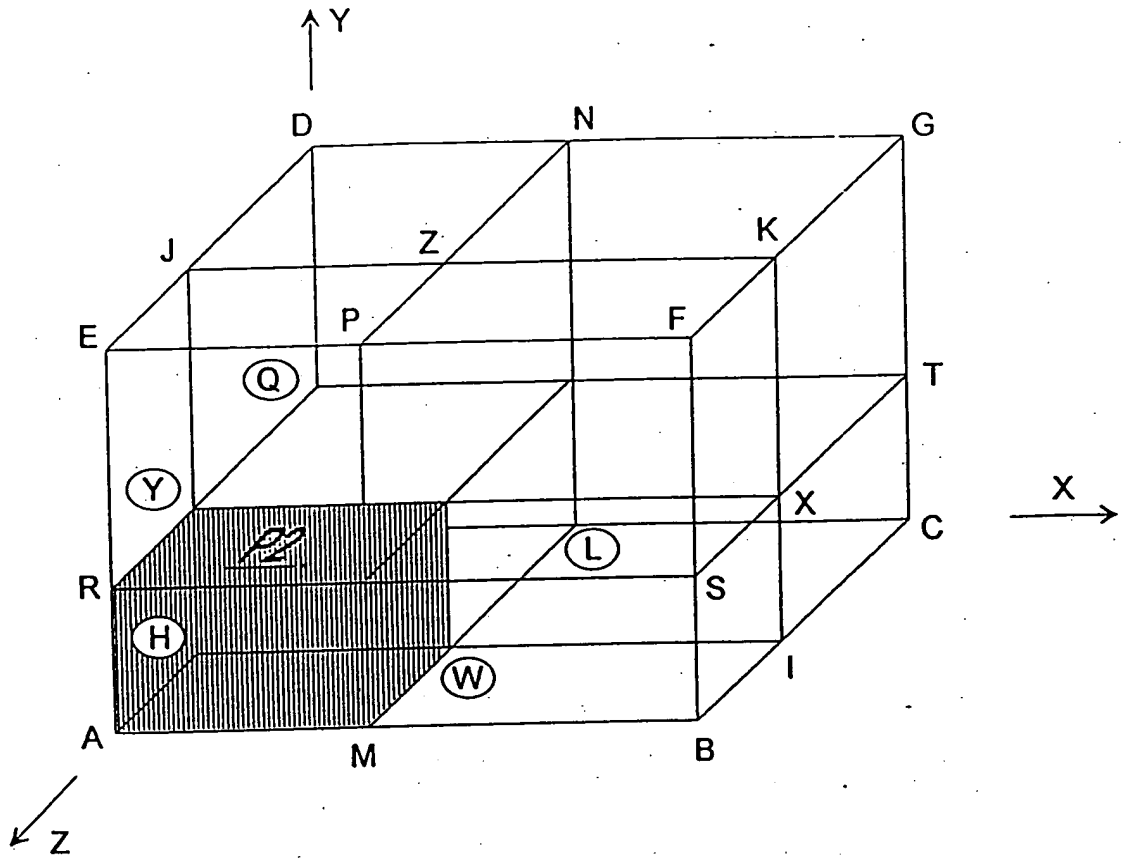

CORNER (30)
Y
CEILING BOUNDARY
2
PALLET BOUNDARY
1
X
A
4
3
BOTTOM BOUNDARY
Z

FIG. 10



	CORNER #	ORIGIN	BOUNDED BY
BEFORE PLACEMENT	1	00	OABC DEFG
AFTER PLACEMENT	2	H	HABI JEFK
	3	L	LMBC NPFG
	4	Q	QRST DEFG

FIG. 11



	CORNER #	ORIGIN	BOUNDED BY
BEFORE PLACEMENT	2	H	HABI JEFK
	3	L	LMBC NPFG
	4	Q	QRST DEFG
AFTER PLACEMENT IN CORNER 2	3	L	LMBC NPFG
	4	Q	QRST DEFG
	5	W	WMIB PFKZ
	6	Y	YRSX JEFK
AFTER MERGING	3	L	LMBC NPFG
	4	Q	QRST DEFG

(CORNER 5 MERGED INTO CORNER 3)

(CORNER 6 MERGED INTO CORNER 4)

FIG. 12

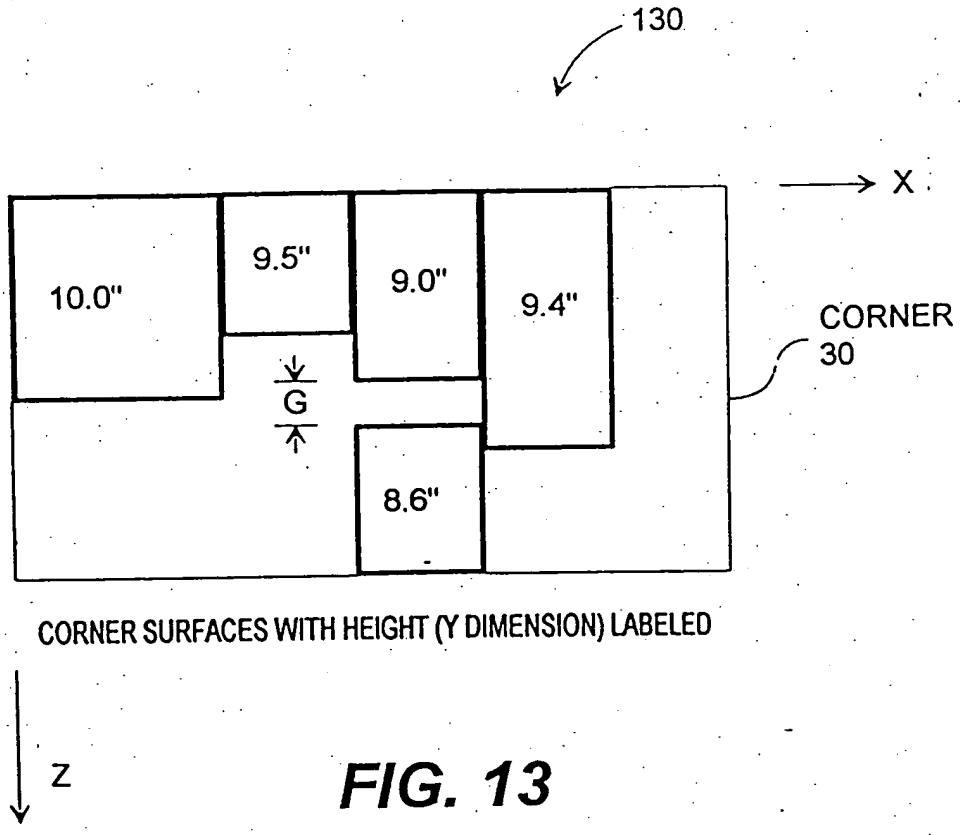

130
X
10.0"
9.5"
9.0"
9.4"
CORNER
30
G
8.6"
CORNER SURFACES WITH HEIGHT (Y DIMENSION) LABELED
Z

FIG. 13

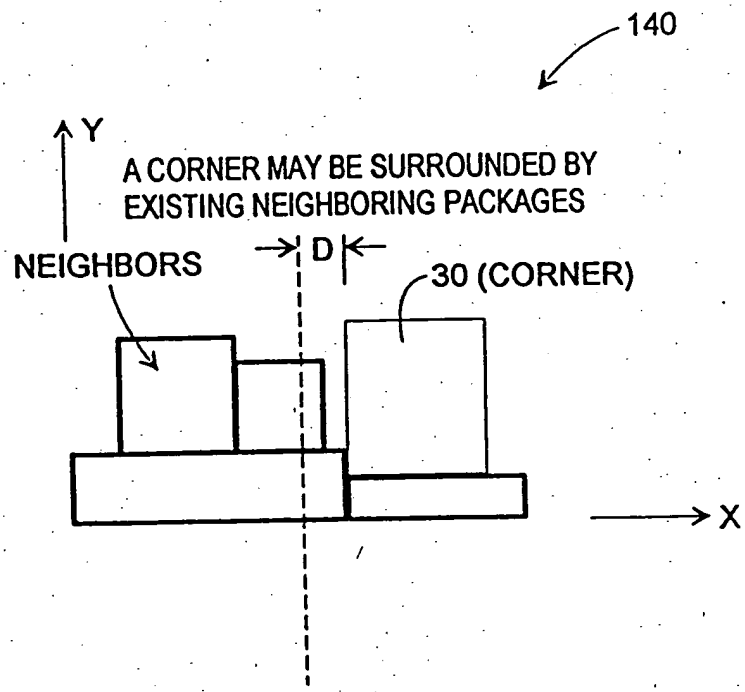

140
Y
A CORNER MAY BE SURROUNDED BY
EXISTING NEIGHBORING PACKAGES
NEIGHBORS
D
30 (CORNER)
X

FIG. 14

FIG. 15A

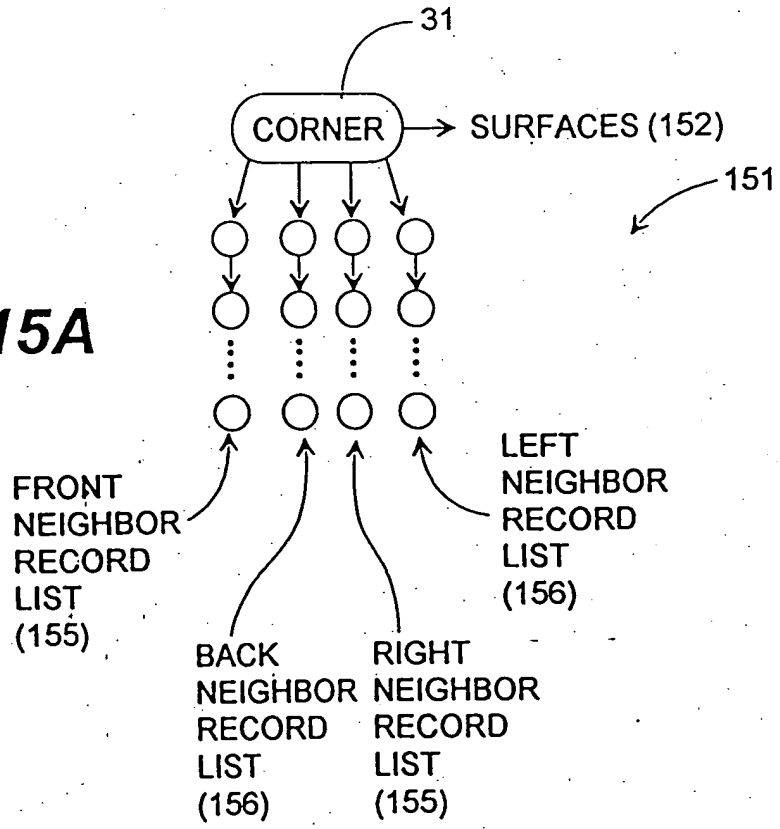
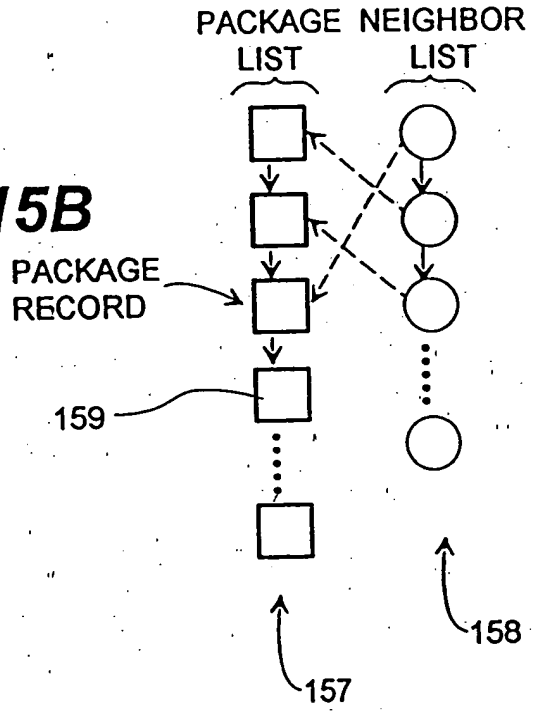


FIG. 15B



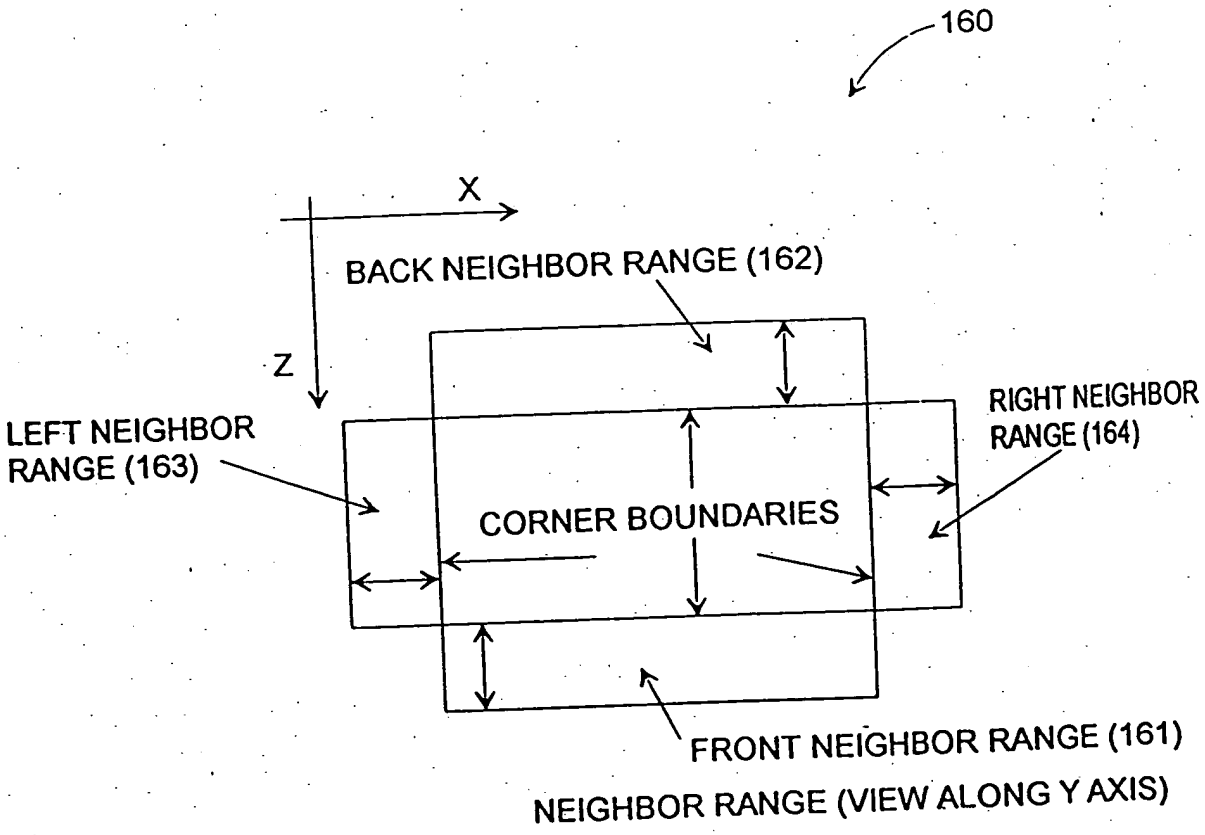

160
X
Z
BACK NEIGHBOR RANGE (162)
LEFT NEIGHBOR RANGE (163)
RIGHT NEIGHBOR RANGE (164)
CORNER BOUNDARIES
FRONT NEIGHBOR RANGE (161)
NEIGHBOR RANGE (VIEW ALONG Y AXIS)

FIG. 16

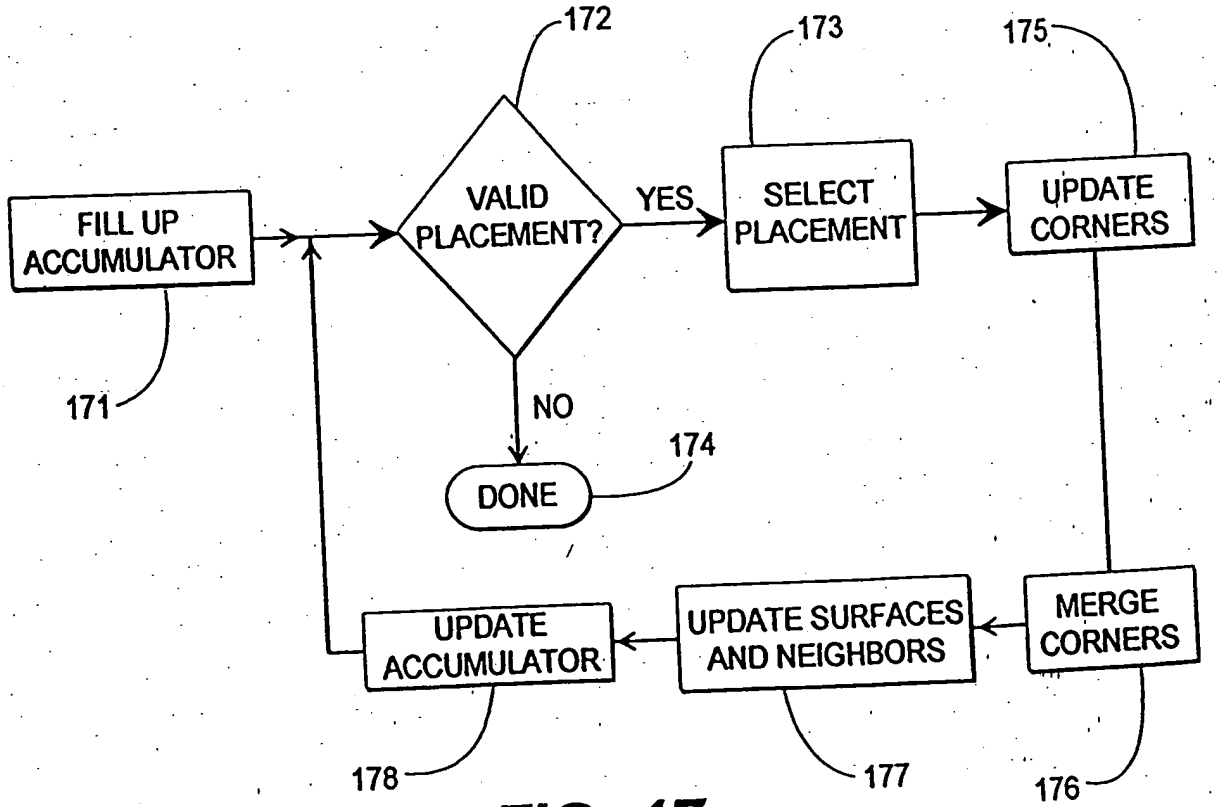

172
173
175
FILL UP ACCUMULATOR
VALID PLACEMENT?
YES
SELECT PLACEMENT
UPDATE CORNERS
171
NO
174
DONE
UPDATE ACCUMULATOR
UPDATE SURFACES AND NEIGHBORS
MERGE CORNERS
178
177
176

FIG. 17

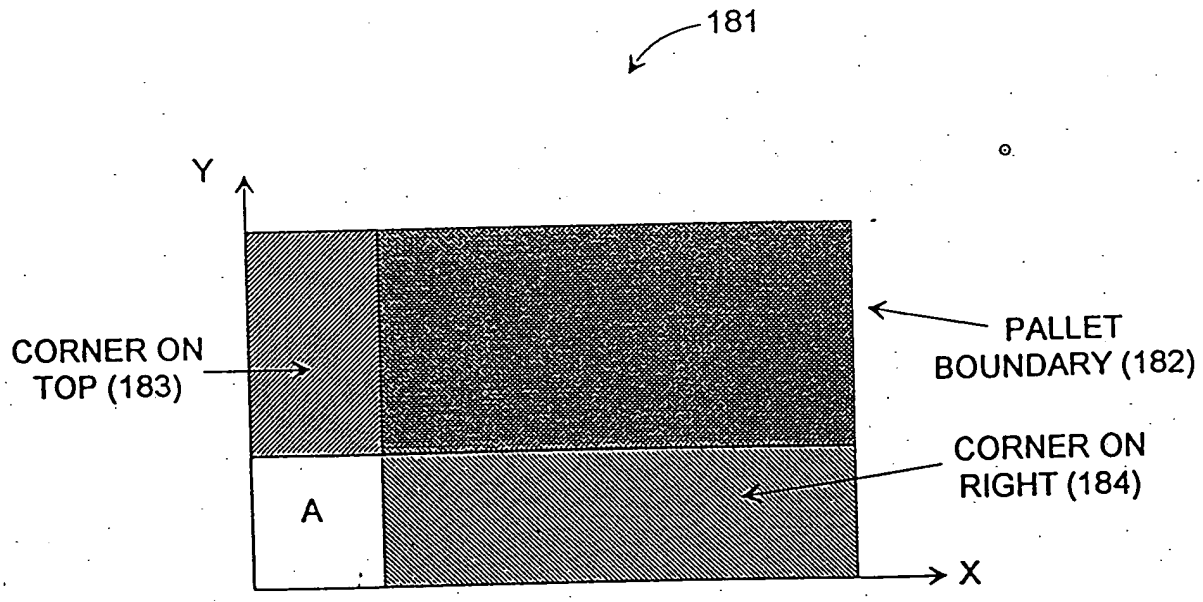


FIG. 18A

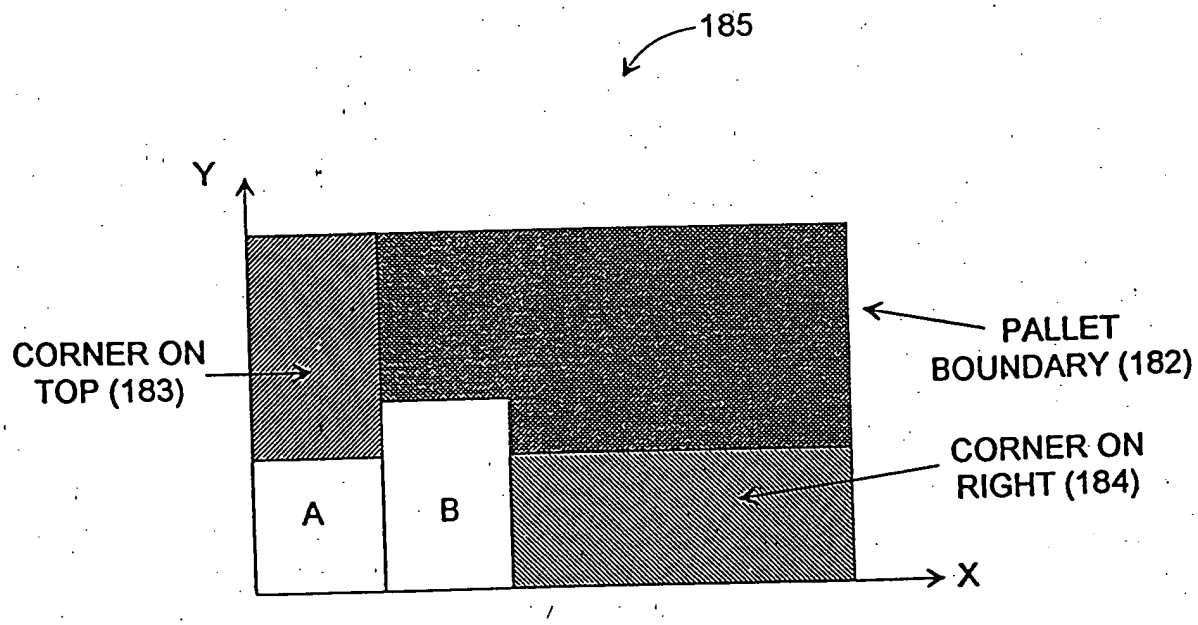
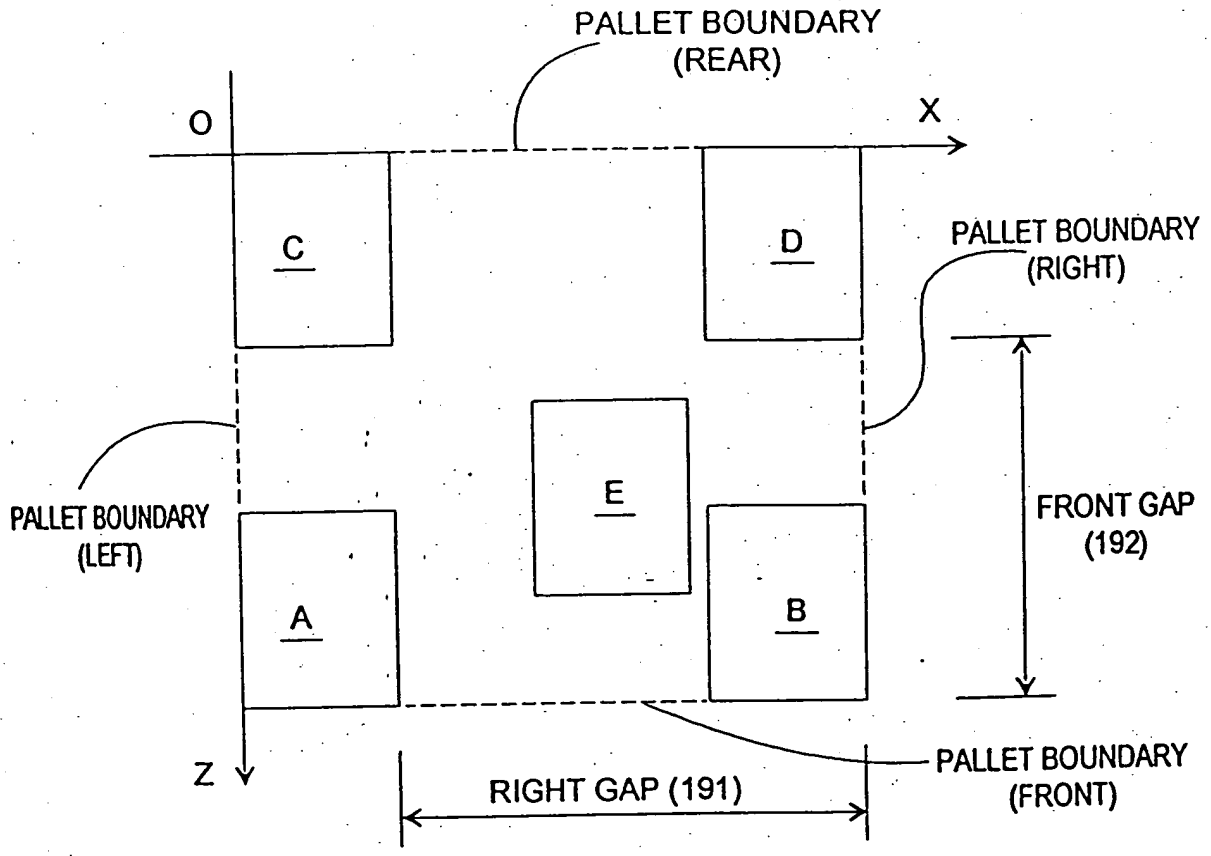


FIG. 18B



POSITION A - FRONT FLUSHING
POSITION B - FRONT AND LEFT FLUSHING
POSITION C - NO FLUSH
POSITION D - RIGHT FLUSH
POSITION E - SHIFTED

PACKAGES C AND D BOTH HAVE FRONT GAP BETWEEN THEMSELVES AND FRONT PALLET BOUNDARY

PACKAGES A AND B HAVE NO FRONT GAP

PACKAGES A AND C BOTH HAVE SAME RIGHT GAP BETWEEN THEMSELVES AND RIGHT PALLET BOUNDARY

PACKAGES B AND D HAVE NO FRONT GAP

FIG. 19

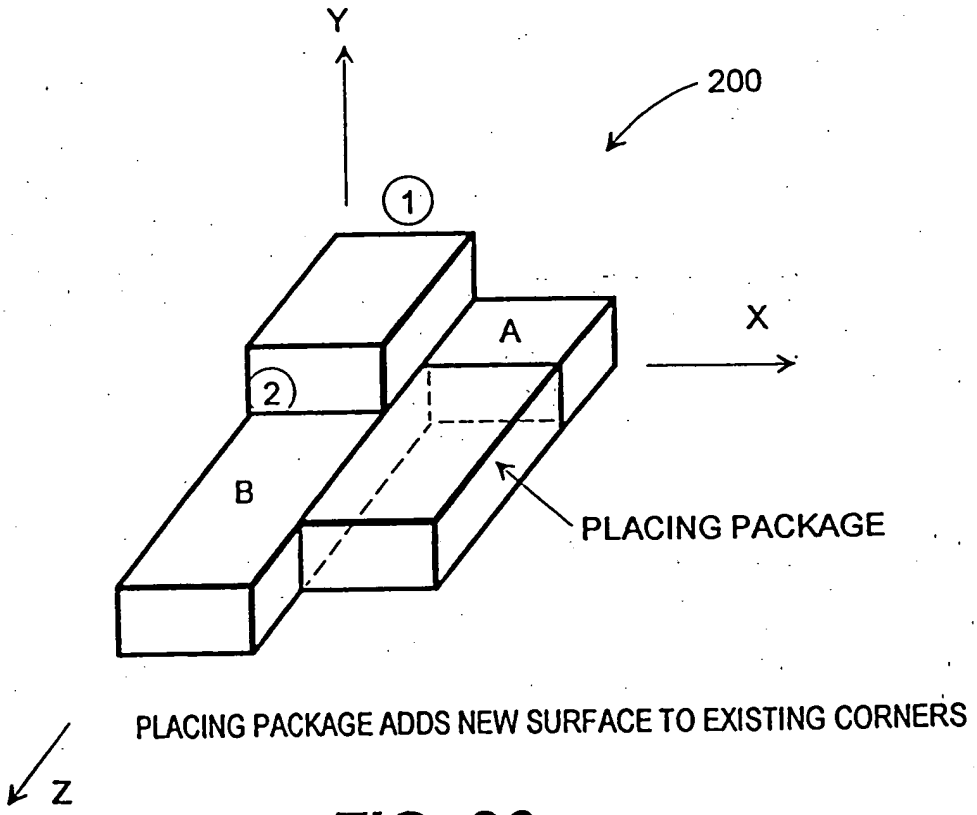

Y
200
1
A
X
2
B
PLACING PACKAGE
PLACING PACKAGE ADDS NEW SURFACE TO EXISTING CORNERS
Z

FIG. 20

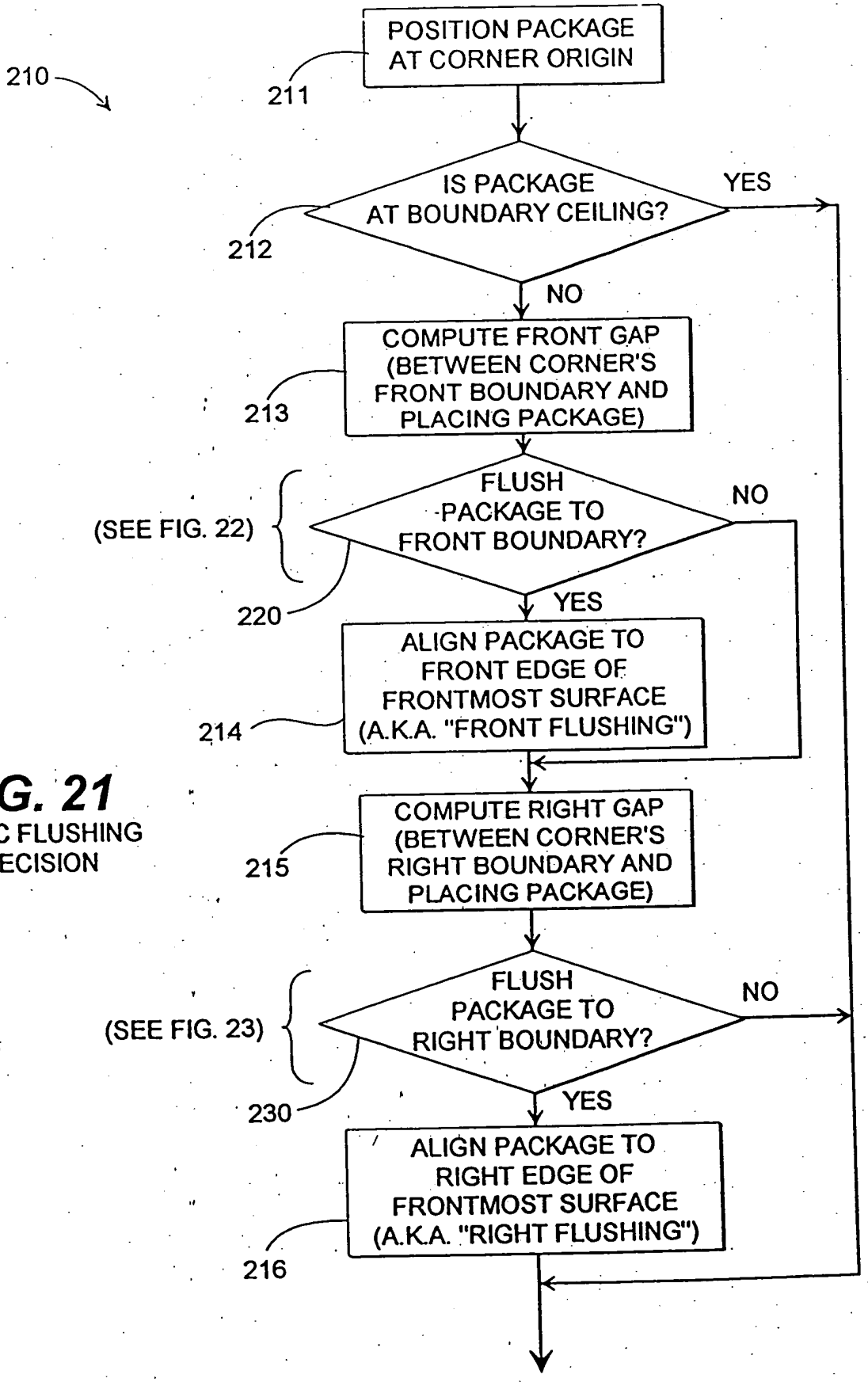


FIG. 21
BASIC FLUSHING DECISION

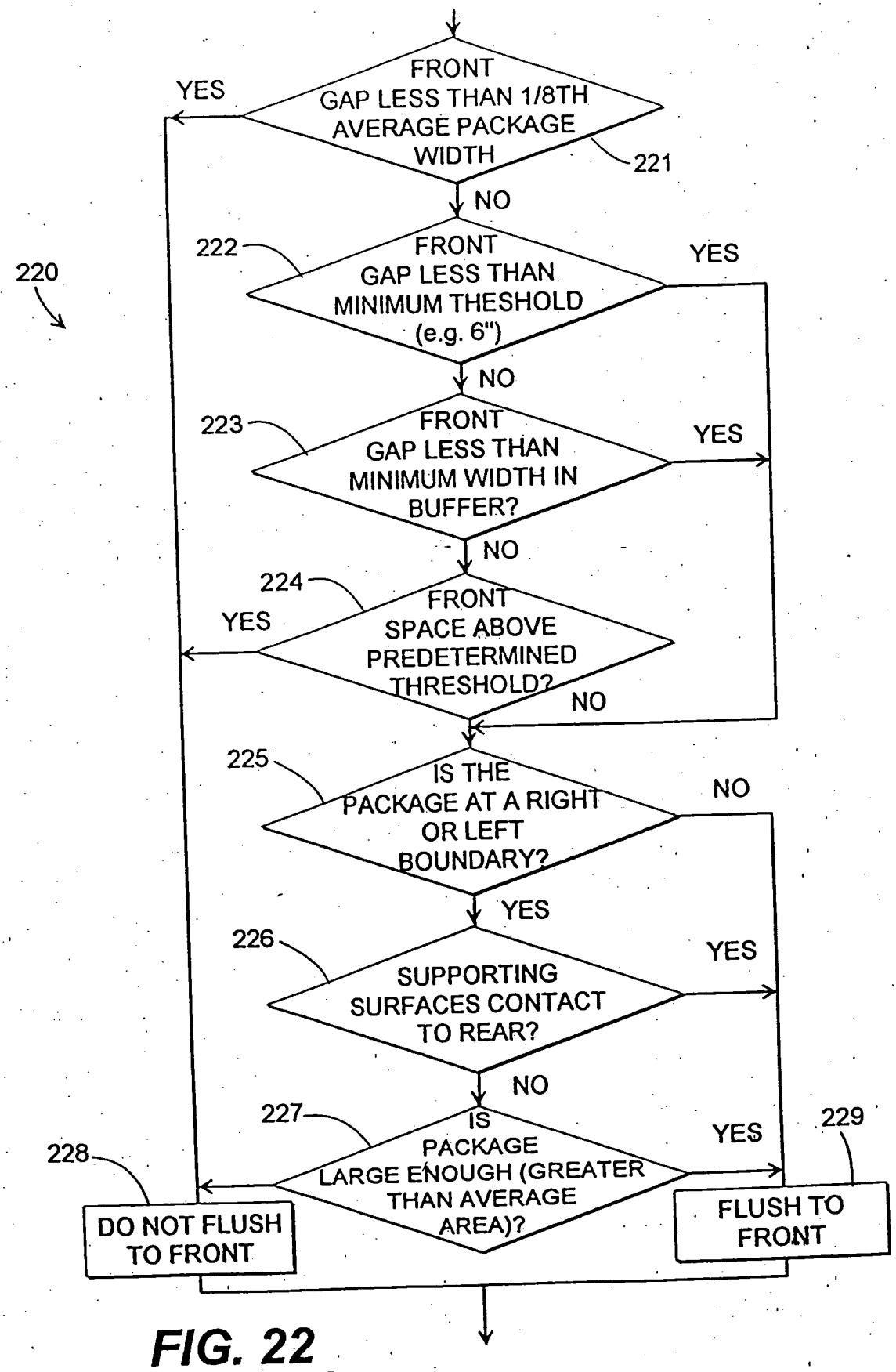


FIG. 22
FRONT FLUSHING DECISION

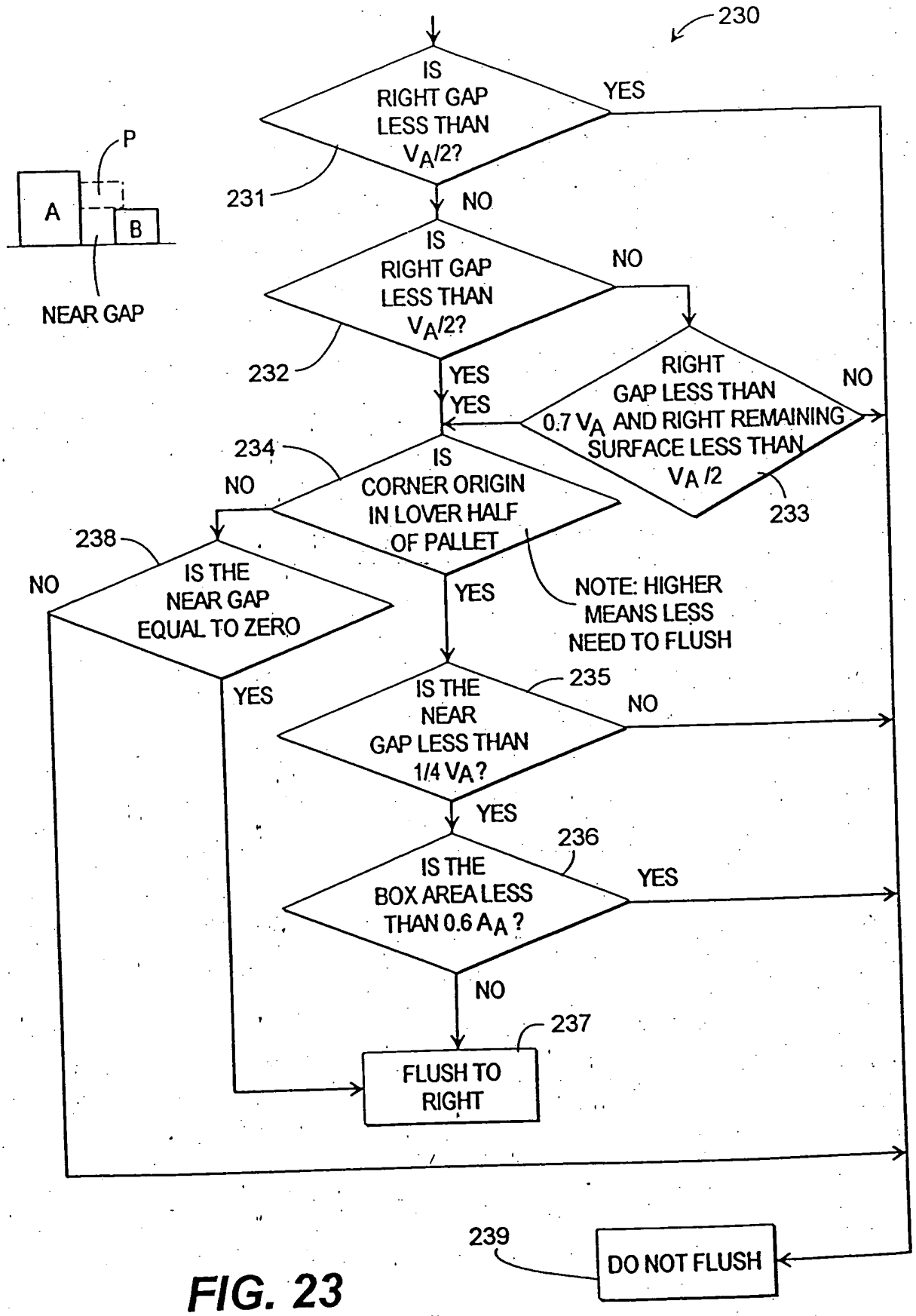


FIG. 23
(RIGHT FLUSHING DECISION)

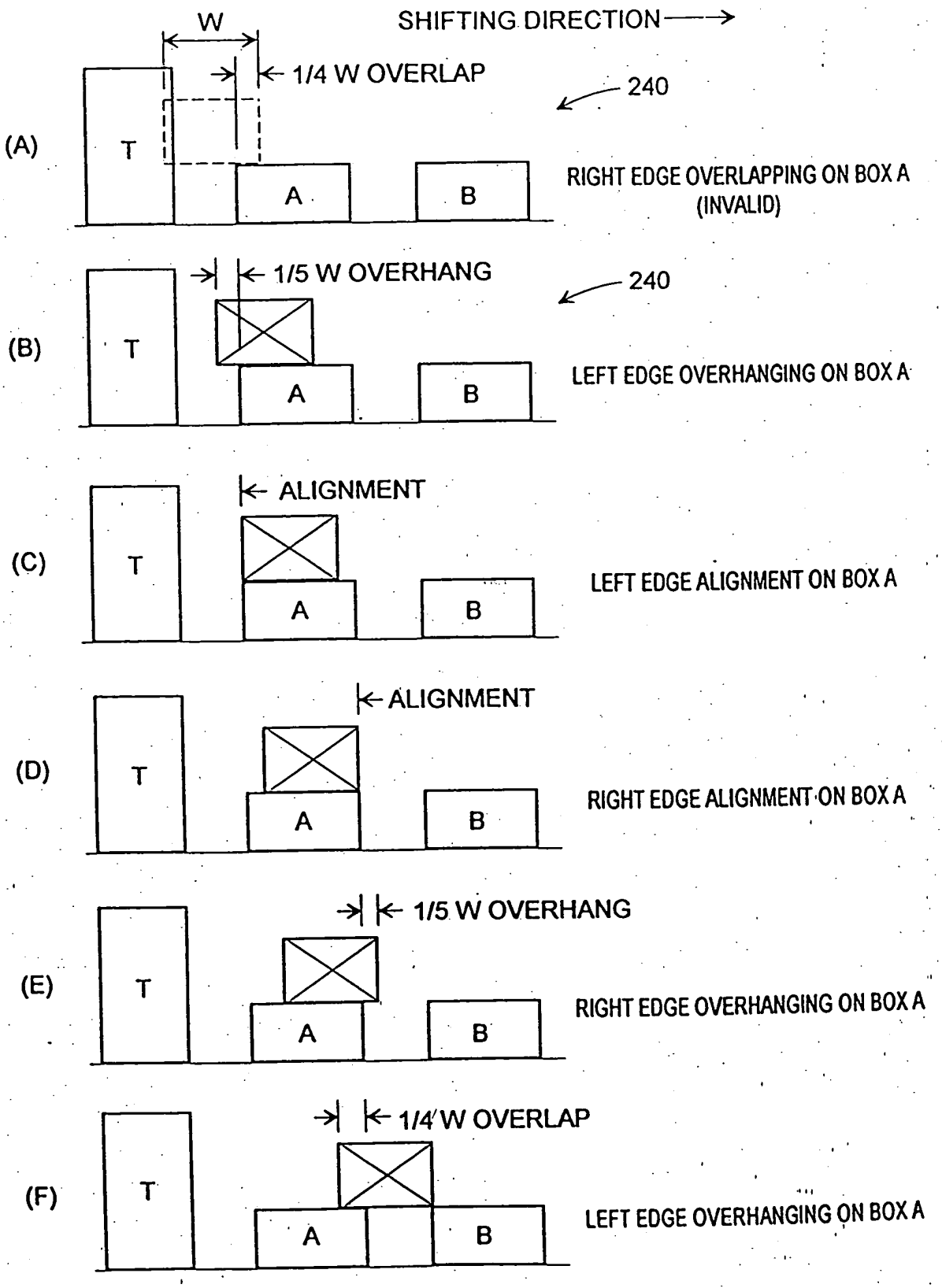

W
SHIFTING DIRECTION
1/4 W OVERLAP
240
(A)
T
A
B
RIGHT EDGE OVERLAPPING ON BOX A
(INVALID)
1/5 W OVERHANG
240
(B)
T
A
B
LEFT EDGE OVERHANGING ON BOX A
ALIGNMENT
(C)
T
A
B
LEFT EDGE ALIGNMENT ON BOX A
ALIGNMENT
(D)
T
A
B
RIGHT EDGE ALIGNMENT ON BOX A
1/5 W OVERHANG
(E)
T
A
B
RIGHT EDGE OVERHANGING ON BOX A
1/4 W OVERLAP
(F)
T
A
B
LEFT EDGE OVERHANGING ON BOX A

FIG. 24

(TWO DIMENSIONAL SHIFTING)

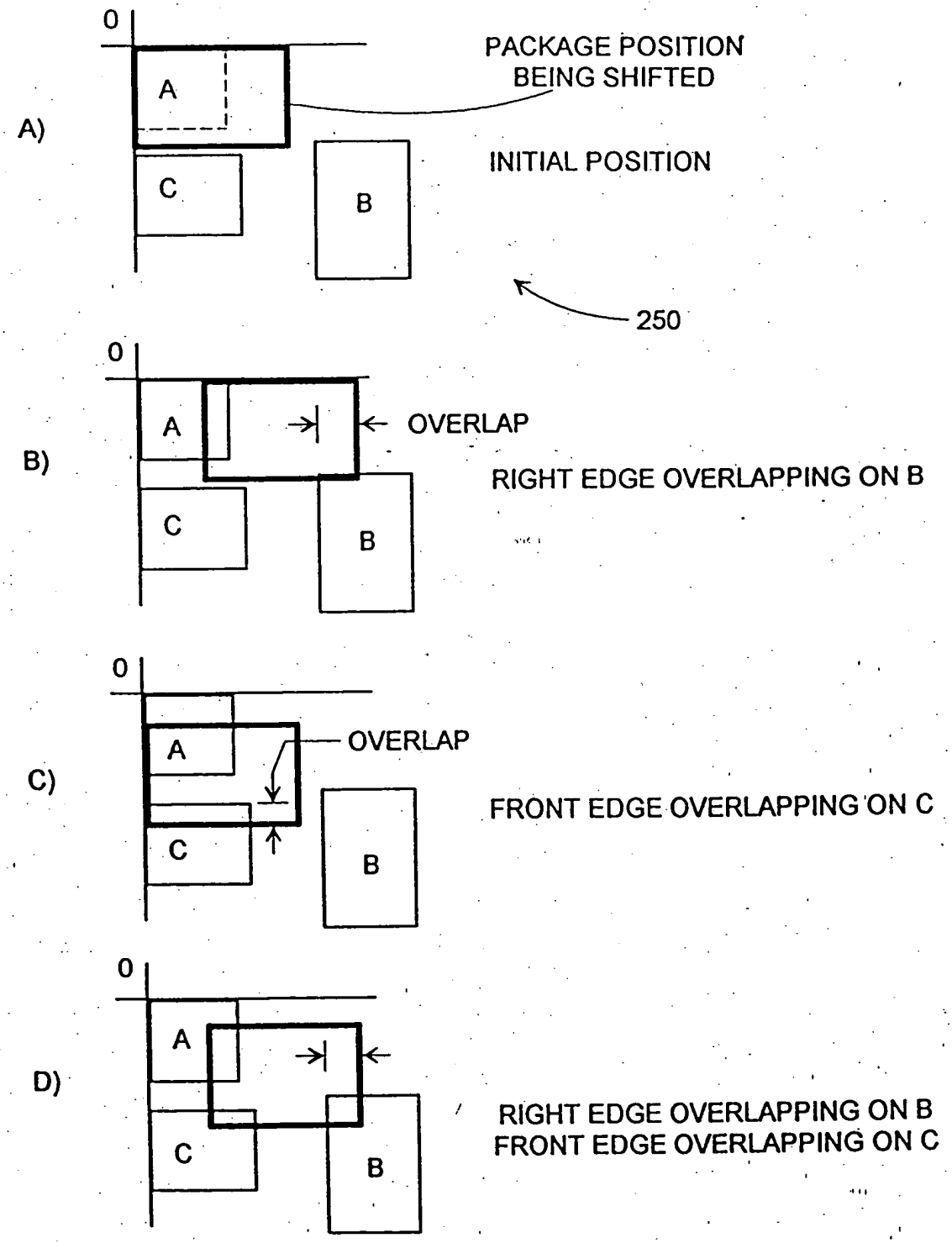
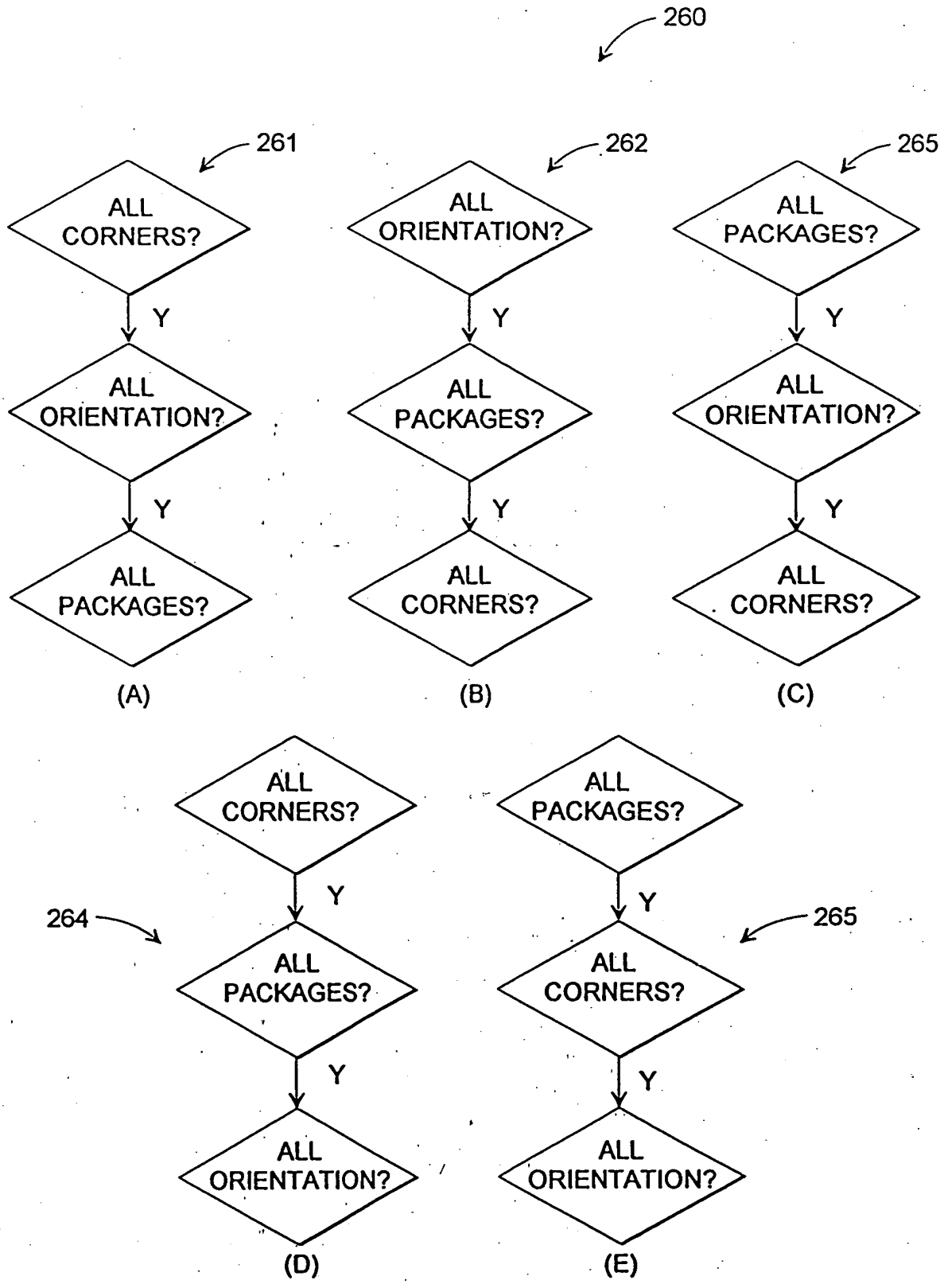


FIG. 25



ALTERNATIVE SELECTION SEQUENCES

FIG. 26

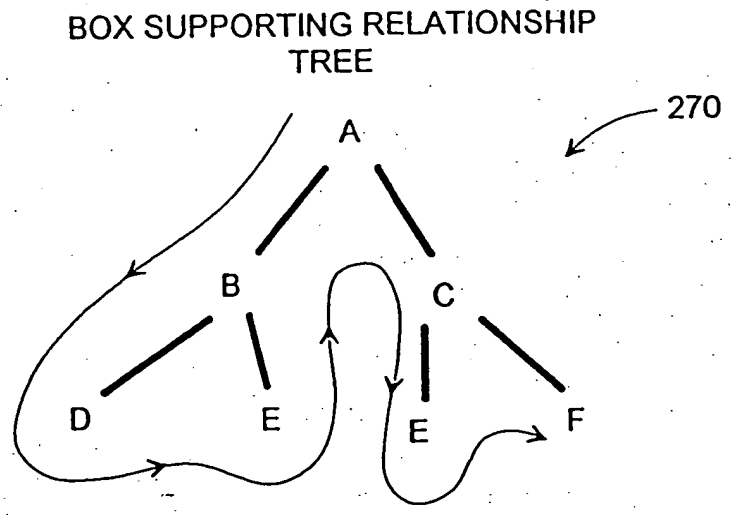

BOX SUPPORTING RELATIONSHIP TREE
270
A
B
C
D
E
E
F

FIG. 27

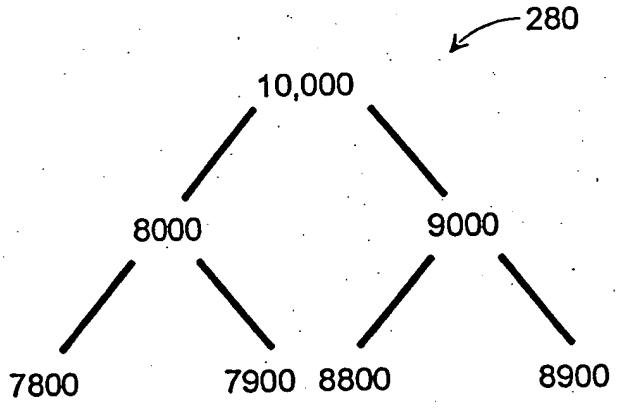

280
10,000
8000
9000
7800
7900
8800
8900

FIG. 28

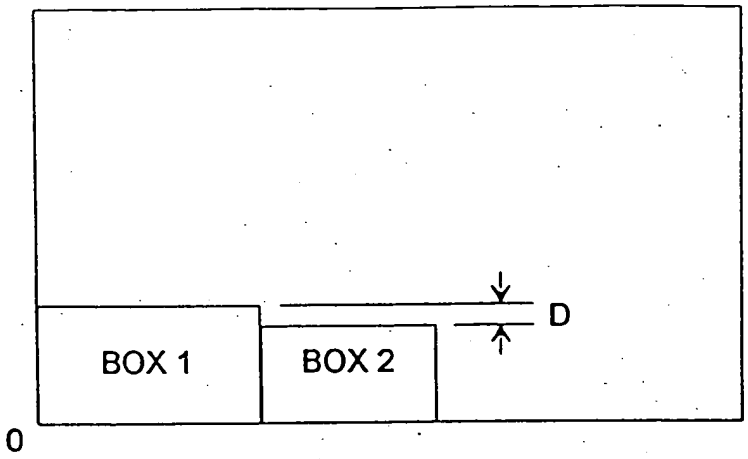


FIG. 29A

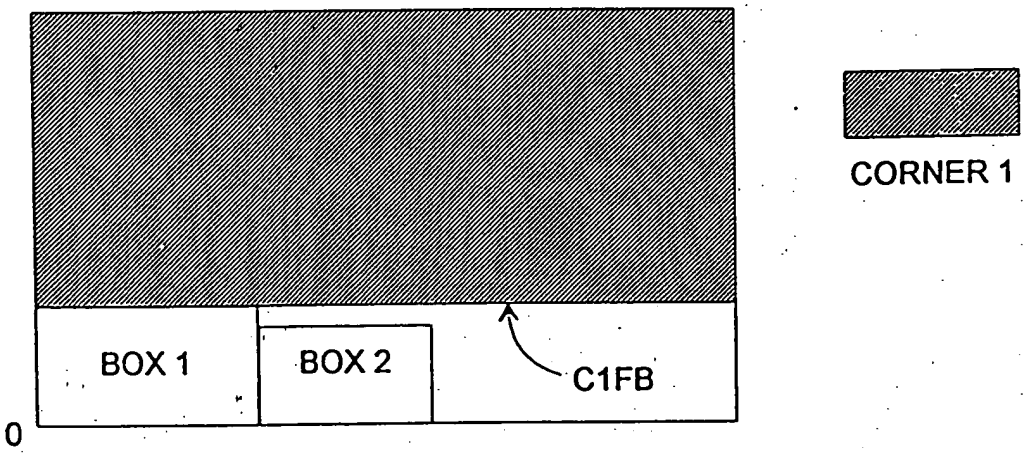


FIG. 29B

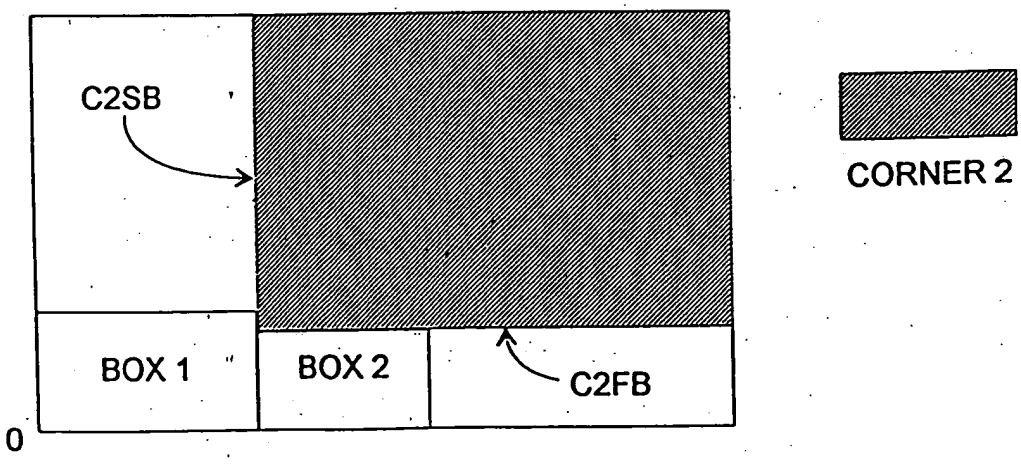


FIG. 29C

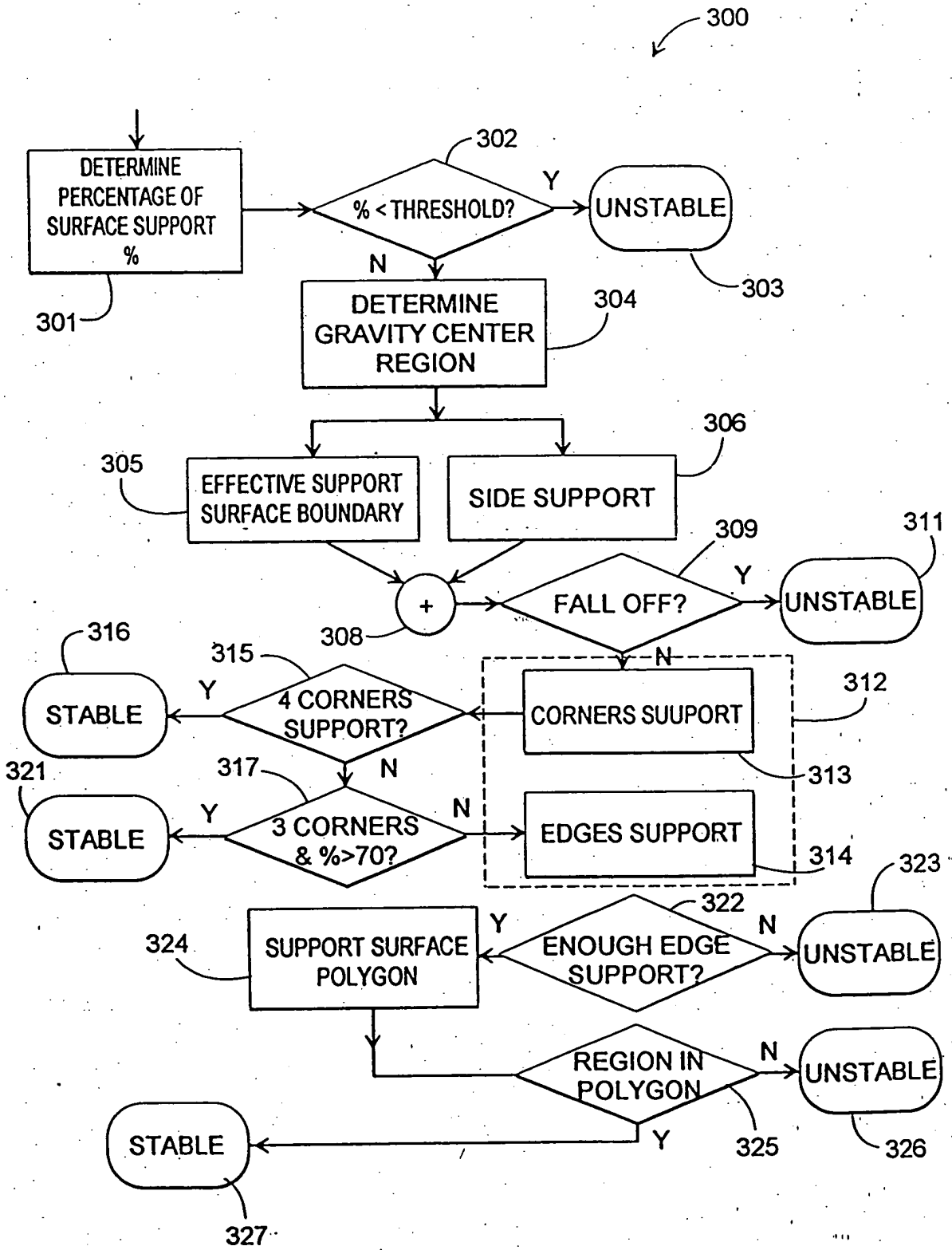

300
DETERMINE PERCENTAGE OF SURFACE SUPPORT %
301
302
% < THRESHOLD?
Y
UNSTABLE
303
N
DETERMINE GRAVITY CENTER REGION
304
305
EFFECTIVE SUPPORT SURFACE BOUNDARY
SIDE SUPPORT
306
+
308
309
FALL OFF?
Y
UNSTABLE
311
N
316
STABLE
Y
315
4 CORNERS SUPPORT?
CORNERS SUUPORT
312
313
N
321
STABLE
Y
317
3 CORNERS & %>70?
N
EDGES SUPPORT
314
323
322
Y
N
324
SUPPORT SURFACE POLYGON
ENOUGH EDGE SUPPORT?
UNSTABLE
N
REGION IN POLYGON
UNSTABLE
STABLE
Y
325
326
327

FIG. 30

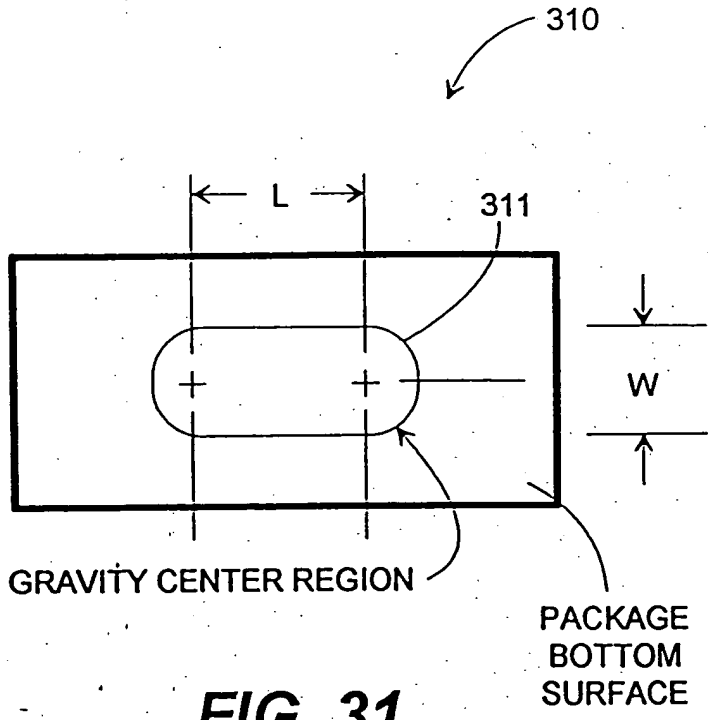

310
L
311
W
GRAVITY CENTER REGION
PACKAGE
BOTTOM
SURFACE

FIG. 31

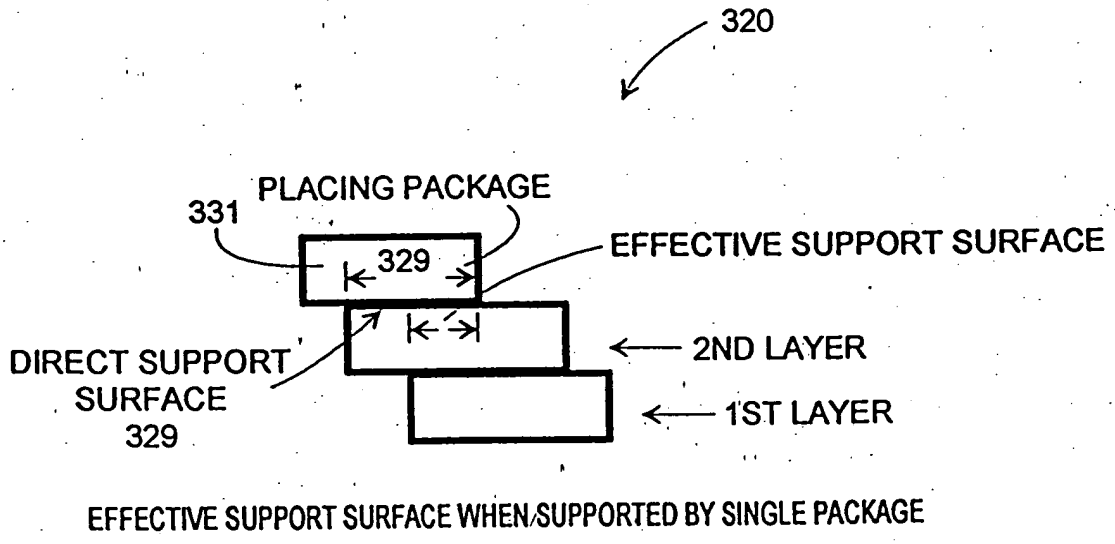
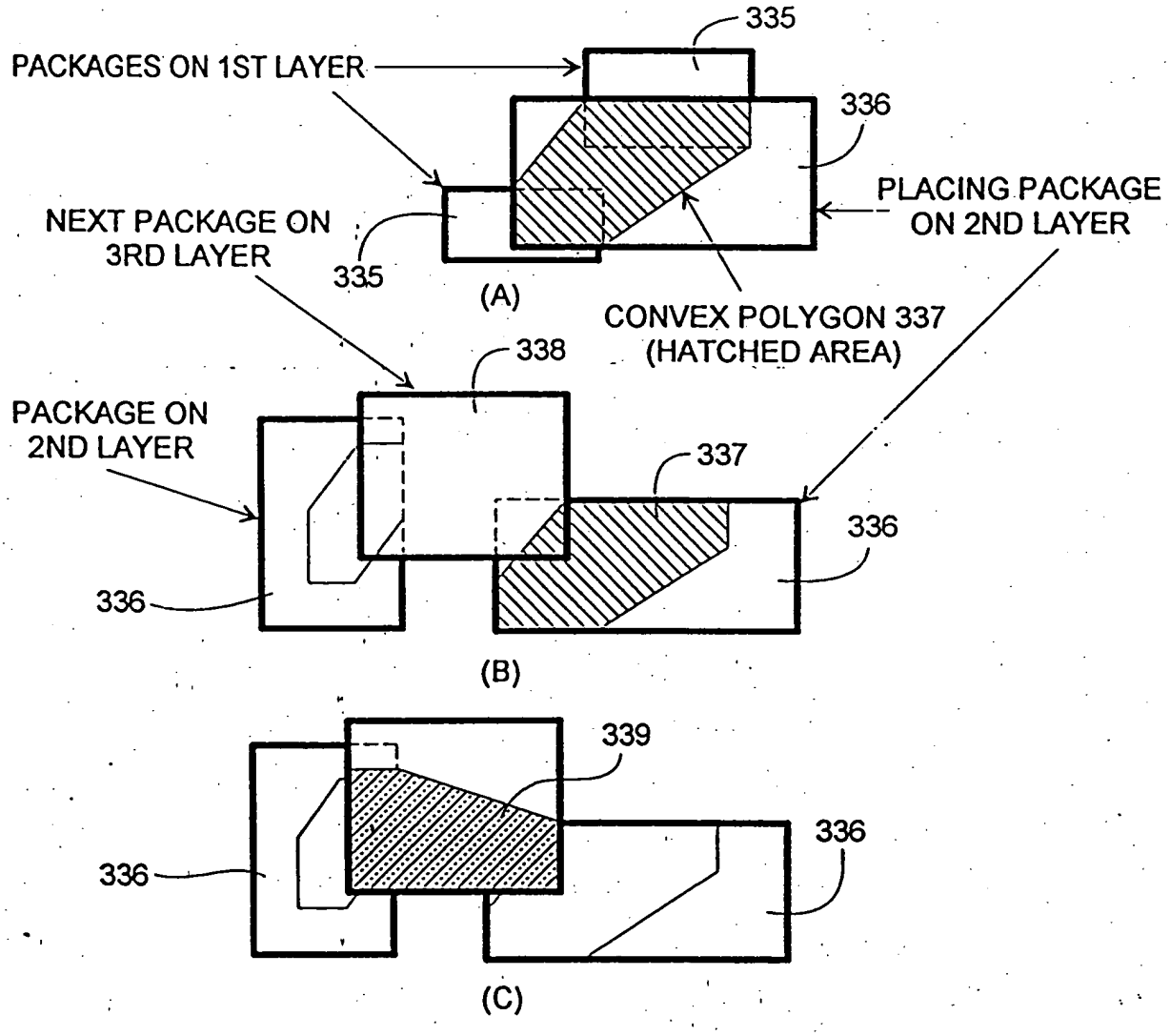
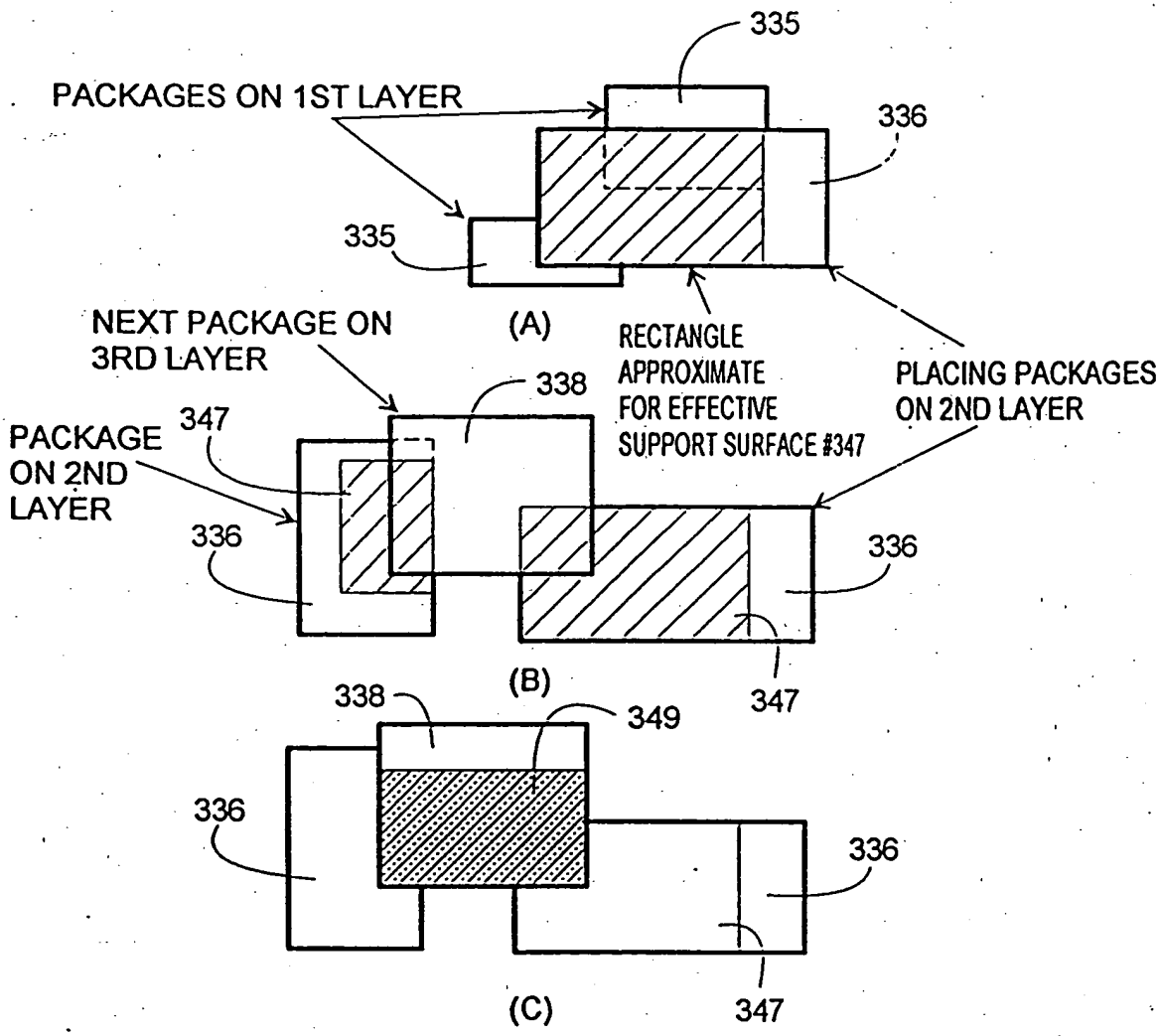

320
PLACING PACKAGE
331
329
EFFECTIVE SUPPORT SURFACE
DIRECT SUPPORT
SURFACE
329
2ND LAYER
1ST LAYER
EFFECTIVE SUPPORT SURFACE WHEN SUPPORTED BY SINGLE PACKAGE

FIG. 32



EFFECTIVE SUPPORT SURFACE WHEN SUPPORTED BY MULTIPLE PACKAGES

FIG. 33



RECTANGLE APPROXIMATE FOR EFFECTIVE SUPPORT SURFACE

FIG. 34

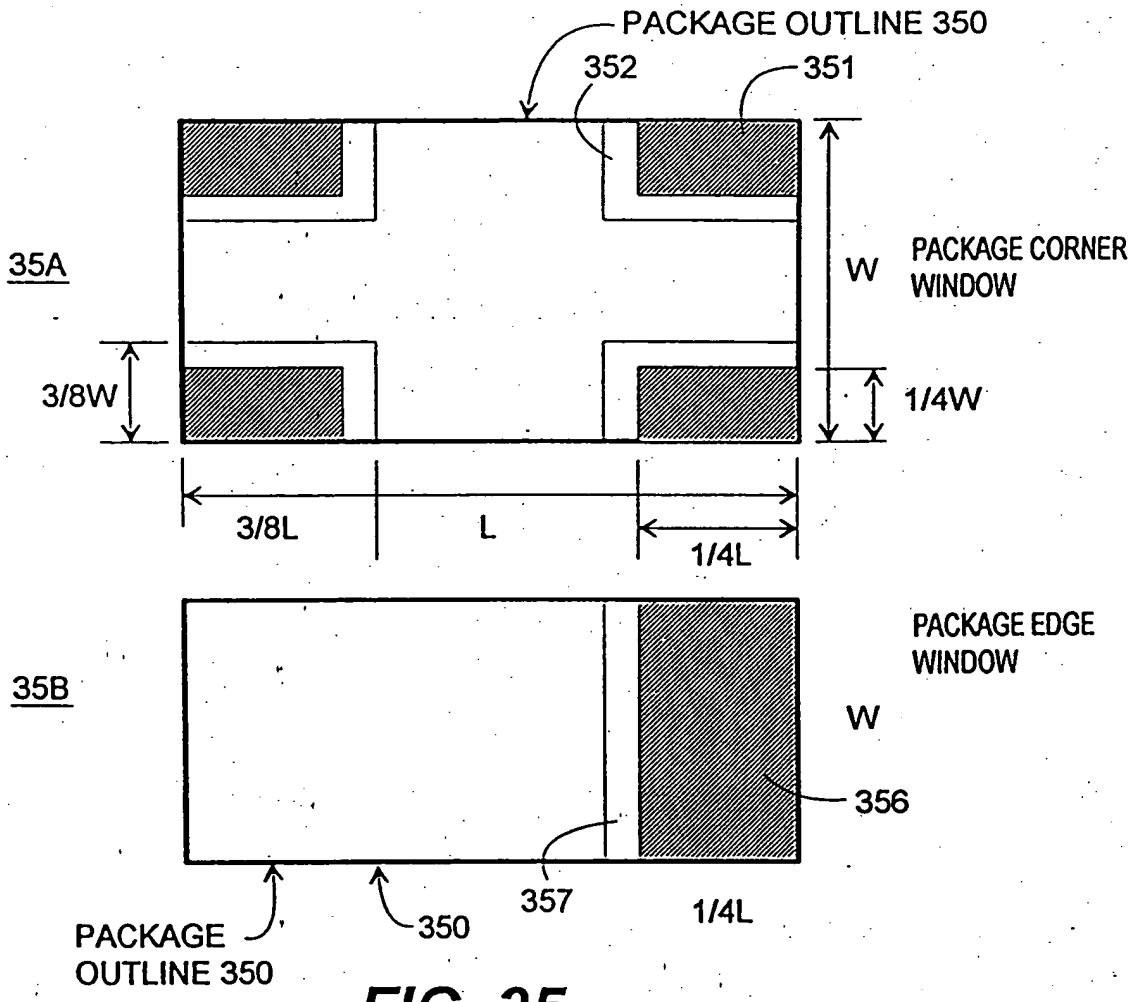
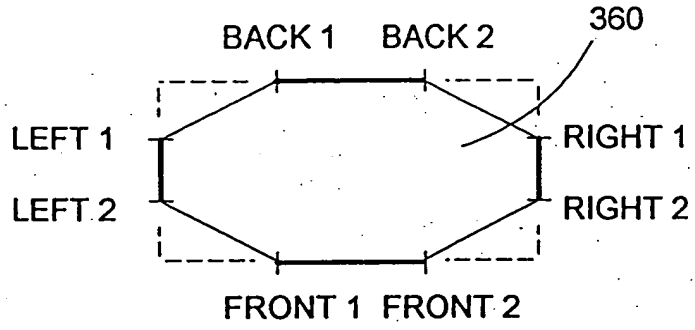
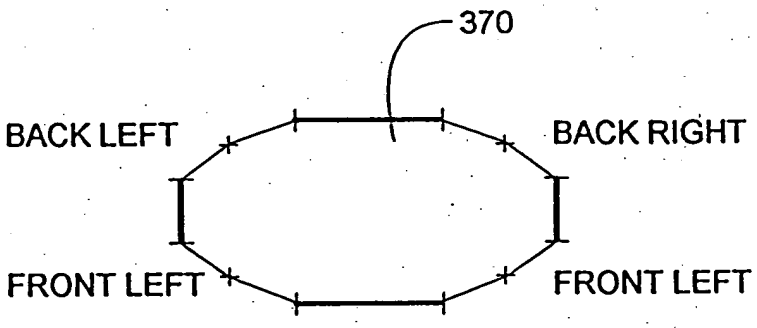

PACKAGE OUTLINE 350
352
351
35A
W
PACKAGE CORNER WINDOW
3/8W
1/4W
3/8L
L
1/4L
35B
PACKAGE EDGE WINDOW
W
356
357
1/4L
350
PACKAGE OUTLINE 350

FIG. 35



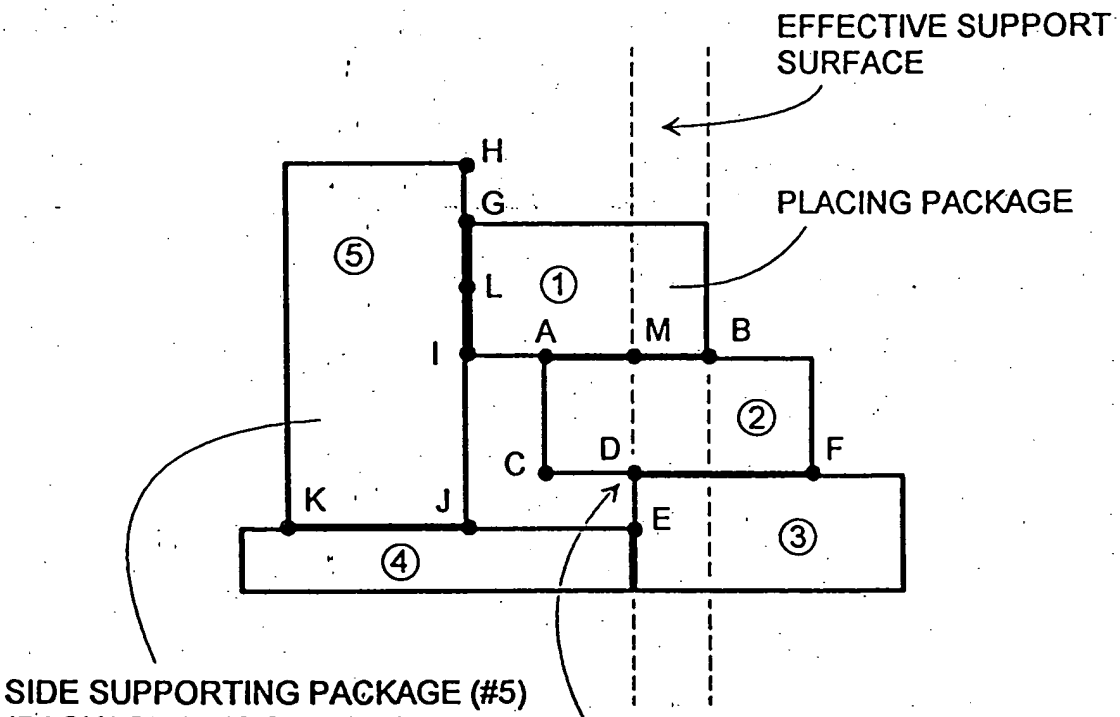
FOUR BOUNDARY EDGES OF A POLYGON

FIG. 36



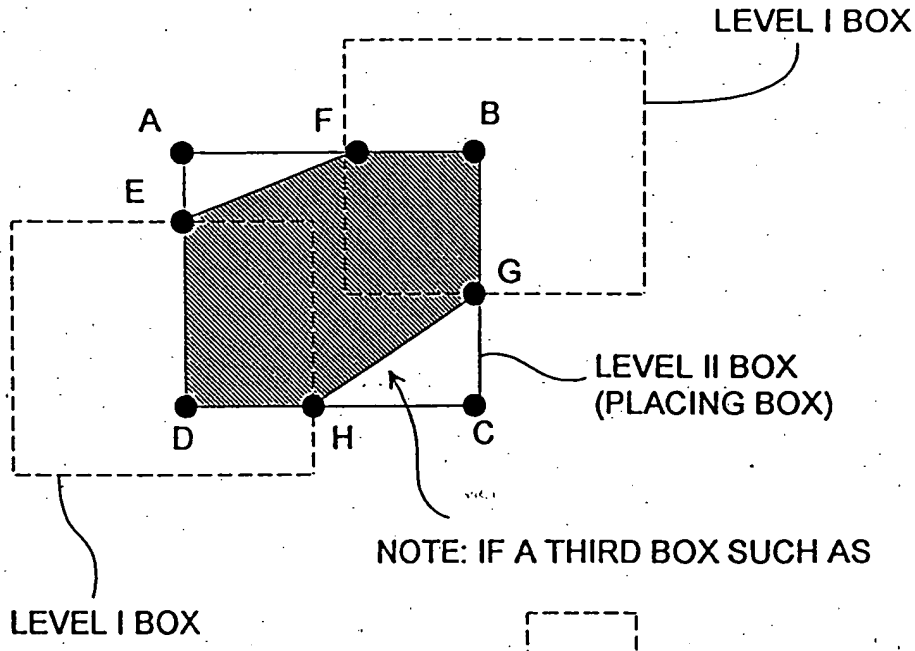
FOUR ADDITIONAL VERTICES

FIG. 37



RE: SIDE SUPPORT

FIG. 38



RE: DIRECT SUPPORT SURFACE POLYGON

FIG. 39

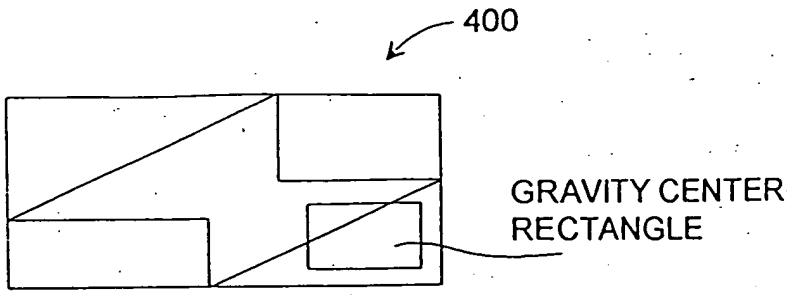


FIG. 40

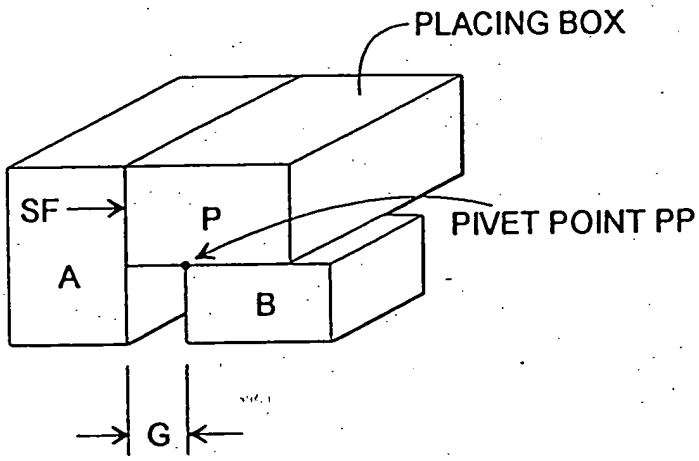


FIG. 41

PACKAGE A PROVIDES SIDE FORCE SF AGAINST PLACING PACKAGE P, WHICH MAY BE SUFFICIENT TO PREVENT PACKAGE P FROM FALLING OFF PACKAGE B ABOUT PIVOT POINT PP.

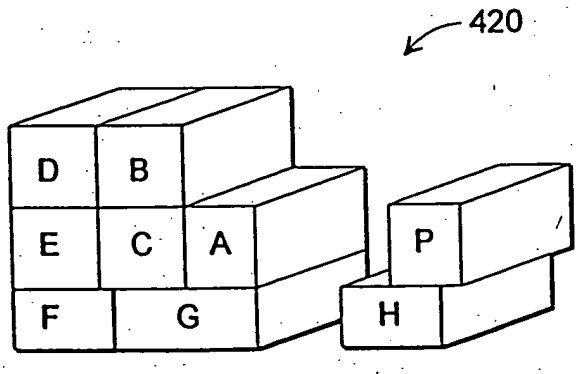
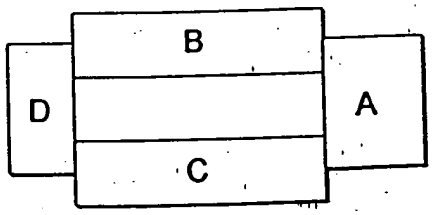


FIG. 42



RE: SIDE WEIGHT PROPAGATION

FIG. 43

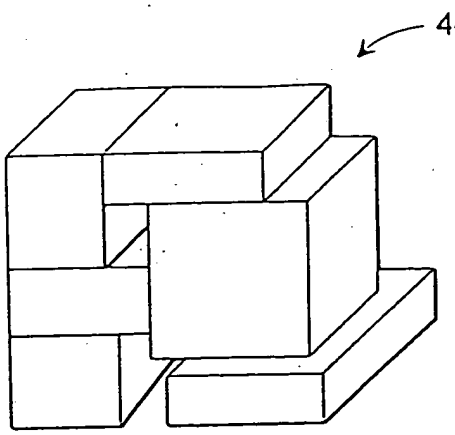

440

FIG. 44

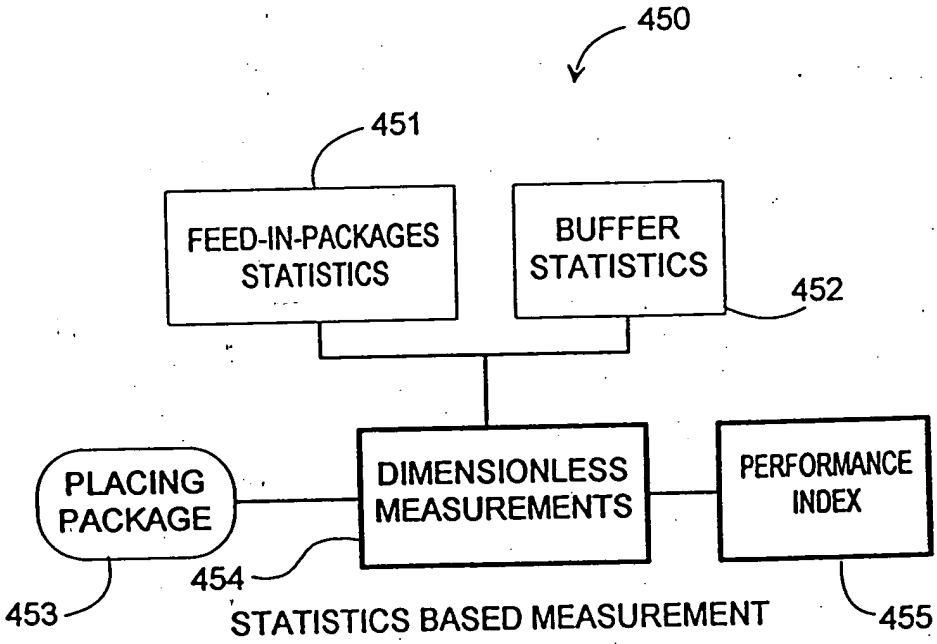

450
451
FEED-IN-PACKAGES STATISTICS
BUFFER STATISTICS
452
PLACING PACKAGE
DIMENSIONLESS MEASUREMENTS
PERFORMANCE INDEX
453
454
STATISTICS BASED MEASUREMENT
455

FIG. 45

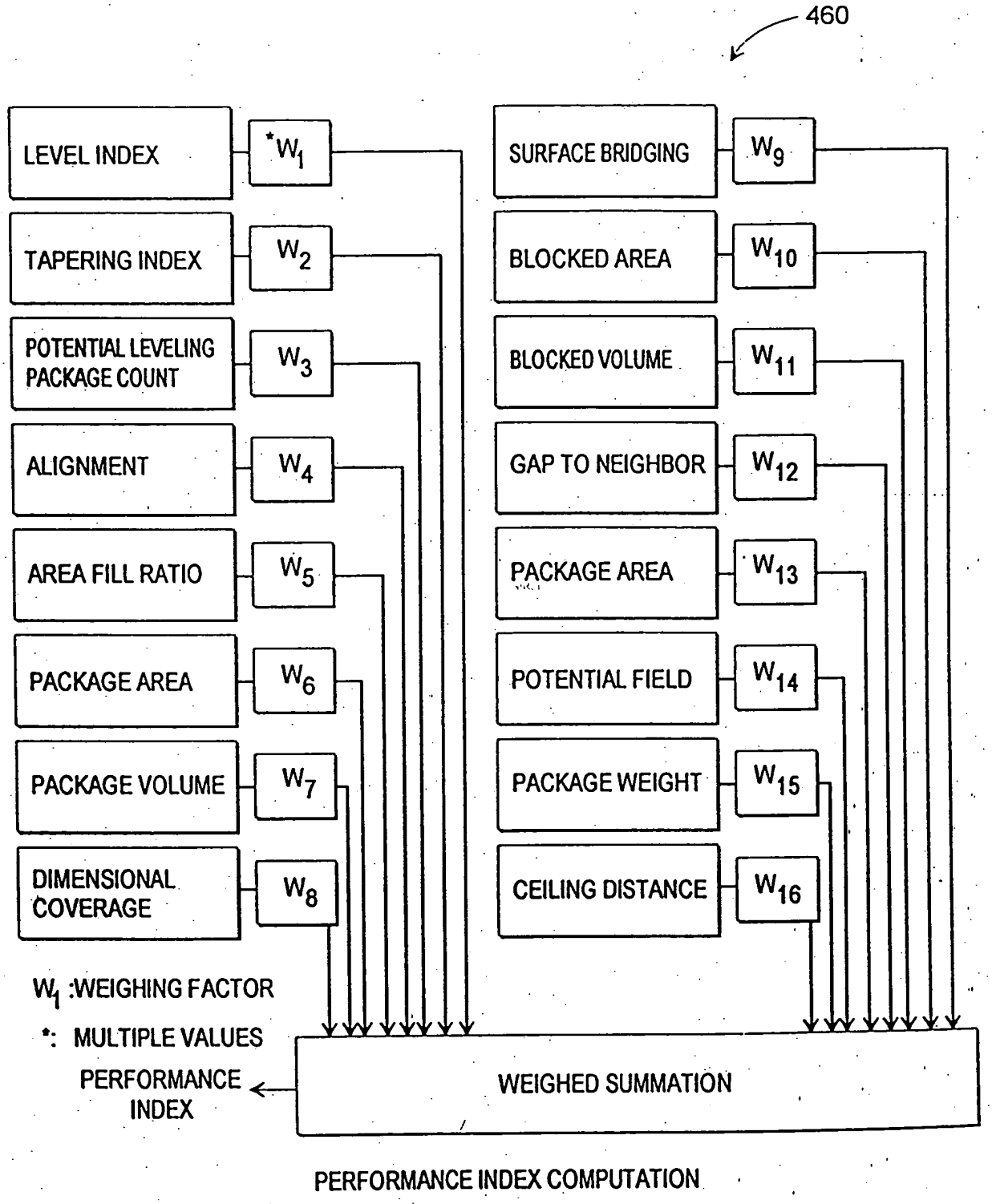
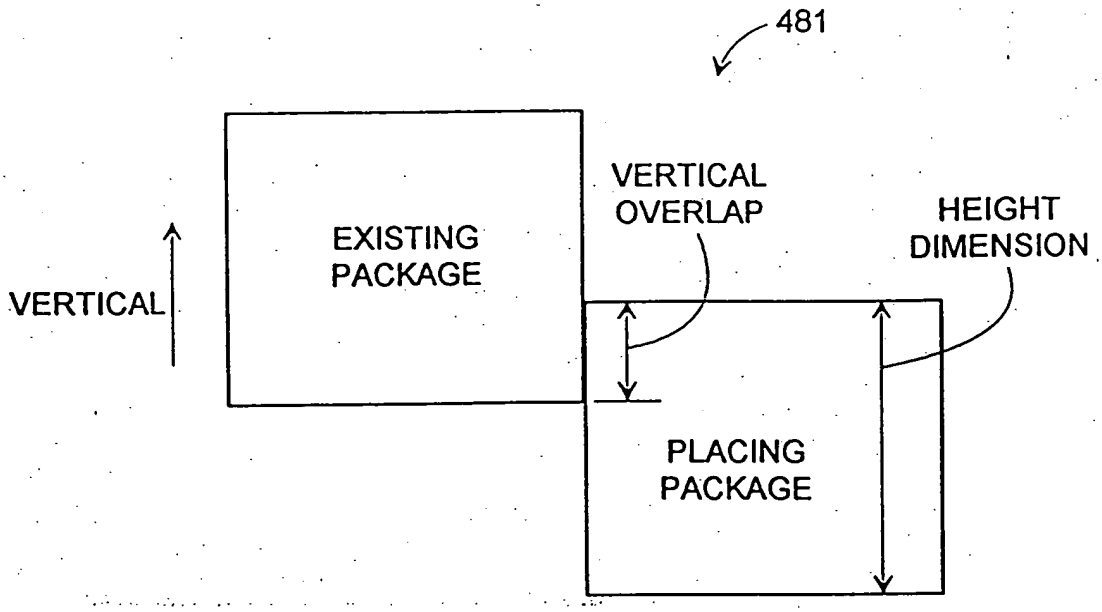

460
LEVEL INDEX
*W1
TAPERING INDEX
W2
POTENTIAL LEVELING PACKAGE COUNT
W3
ALIGNMENT
W4
AREA FILL RATIO
W5
PACKAGE AREA
W6
PACKAGE VOLUME
W7
DIMENSIONAL COVERAGE
W8
SURFACE BRIDGING
W9
BLOCKED AREA
W10
BLOCKED VOLUME
W11
GAP TO NEIGHBOR
W12
PACKAGE AREA
W13
POTENTIAL FIELD
W14
PACKAGE WEIGHT
W15
CEILING DISTANCE
W16
W1 :WEIGHING FACTOR
*: MULTIPLE VALUES
PERFORMANCE INDEX
WEIGHED SUMMATION
PERFORMANCE INDEX COMPUTATION

FIG. 46

W_1	LEVEL INDEX	LEVEL TO ALL NEIGHBORS BONUS:	1600
		LEVEL TO BACK NEIGHBOR BONUS:	1100
		BLOCK BACK PENALTY:	-4000
		ABOVE NEIGHBOR PENALTY:	-2600
		BELOW NEIGHBOR PENALTY:	-600
W_2	TAPERING INDEX	TAPERING INDEX PENALTY:	-800 *TAPERING INDEX
W_3		POTENTIAL LEVEL PACKAGES:	100 *POTENTIAL LEVELING PACKAGES COUNT (APPLICABLE WHEN START A NEW SHELF OR SUB-SHELF)
W_6		PACKAGE GROUP AREA:	50 *VOLUME/AVERAGE VOLUME (APPLICABLE WHEN STARTING NEW SHELF, PACKAGE IS NEAR BOUNDARY, OR PACKAGE TO COVER A GAP, ETC.)
W_7		PACKAGE GROUP VOLUME:	50 *VOLUME/APPLICABLE VOLUME (APPLICABLE WHEN STARTING NEW SHELF, PACKAGE IS NEAR BOUNDARY, OR PACKAGE TO COVER A GAP, ETC.)
W_8		DIMENSIONAL COVERAGE RATION BONUS:	400 *DIMENSIONAL COVERAGE RATIO (FRONT/BACK AND LEFT/RIGHT)
W_4		NEIGHBOR ALIGNMENT BONUS:	100 *NUMBER OF ALIGNMENTS
W_5		AREA FILL BONUS:	200 *CORNER AREA FILL RATIO (APPLICABLE FOR SMALL CORNER)
W_9		SURFACE BRIDGE:	50 *NUMBER OF SURFACE BRIDGING * NUMBER OF TOWERING INDEX
W_{11}		BLOCK VOLUME PENALTY:	-60 *BLOCKED VOLUME/AVERAGE VOLUME
W_{10}		BLOCK AREA PENALTY:	-60 *BLOCKED AREA/AVERAGE AREA
W_{13}		PACKAGE OLD AGE BONUS:	8 *PACKAGE AGE (APPLICABLE WHEN AGE IS ABOVE AN AGE THRESHOLD SUCH AS 10)
W_{15}		PACKAGE WEIGHT BONUS/PENALTY:	400 *(PACKAGE WEIGHT - WEIGHT THRESHOLD) /(MAX WEIGHT - WEIGHT THRESHOLD) *DISTANCE TO HEIGHT THRESHOLD /MAXIMUM DISTANCE (APPLICABLE WHEN PACKAGE WEIGHT IS ABOVE WEIGHT THRESHOLD)
W_{12}		NEIGHBOR GAP PENALTY:	-800 *CORNER AND TOP GAPS/ AVERAGE PACKAGE WIDTH
W_{14}		CORNER HEIGHT:	-2000 #CORNER HEIGHT *PALLET HEIGHT
		CORNER BACK DISTANCE PENALTY:	-60 *CORNER DISTANCE TO BACK BOUNDARY *PALLET DEPTH /MAX(PALLET DEPTH, PALLET LENGTH)
		CORNER SIDE DISTANCE PENALTY:	-60 *CORNER DISTANCE TO LEFT BOUNDARY *PALLET LENGTH /MAX(PALLET DEPTH, PALLET LEGTH)
W_{16}		DISTANCE TO CEILING PENALTY:	-800 *DISTANCE TO CEILING/ AVERAGE PACKAGE HEIGHT (APPLICABLE WHEN PACKAGE IS ON THE TOP LAYER OF THE STACK)

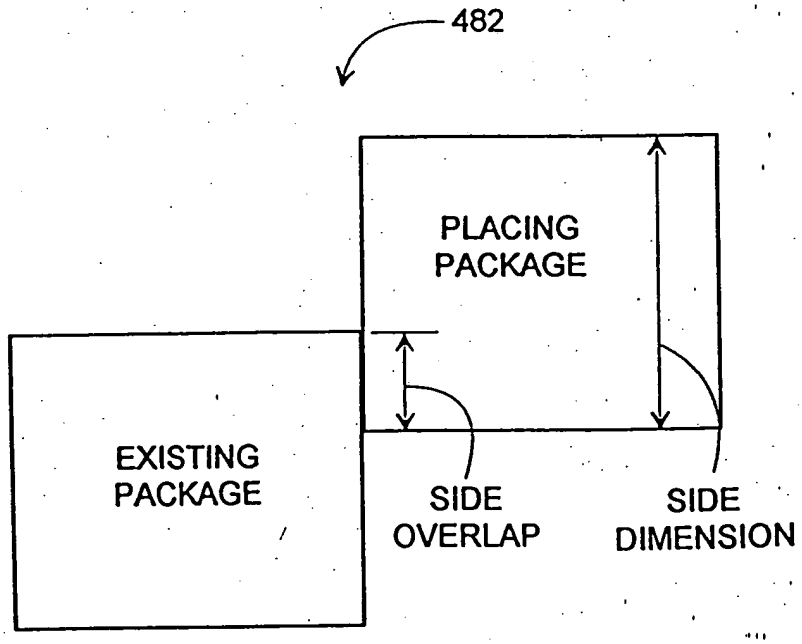
APPENDIX OF WEIGHING FACTORS W_i IN PERFORMANCE INDEX (SEE FOG 46)

FIG. 47



FRONT VIEW

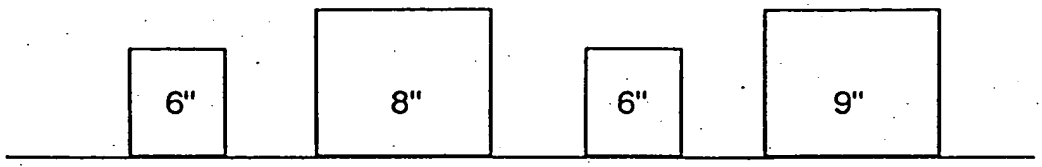
FIG. 48A



TOP VIEW (BIRD'S EYE VIEW)

FIG. 48B

A: INITIALLY IN BUFFER THERE ARE 4 BOXES WHOSE HIEGHT ARE AS SHOWN IN THE FIGURE

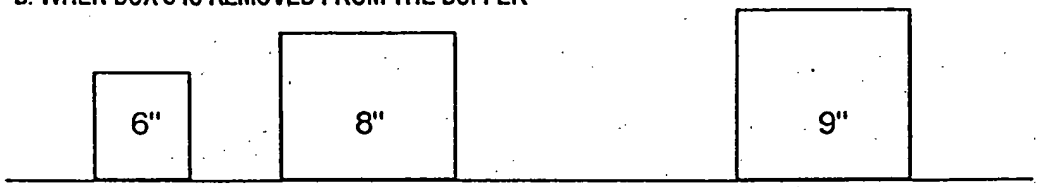


BOX 1 BOX 2 BOX 3 BOX 4

THE CORRESPONDING MATCHING HEIGHT COUNT FOR EACH BOX IS

1 0 1 0

B: WHEN BOX 3 IS REMOVED FROM THE BUFFER

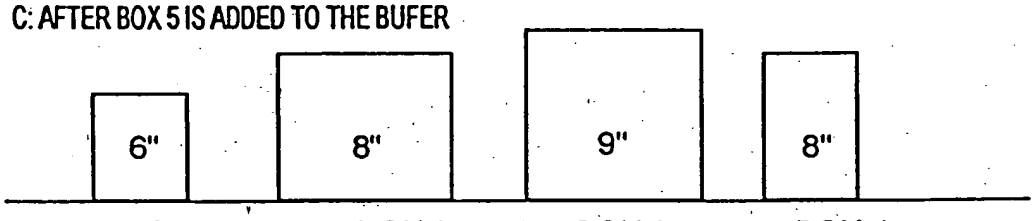


BOX 1 BOX 2 BOX 4

THE CORRESPONDING MATCHING HEIGHT COUNT FOR EACH BOX IS

0 0 0

C: AFTER BOX 5 IS ADDED TO THE BUFER



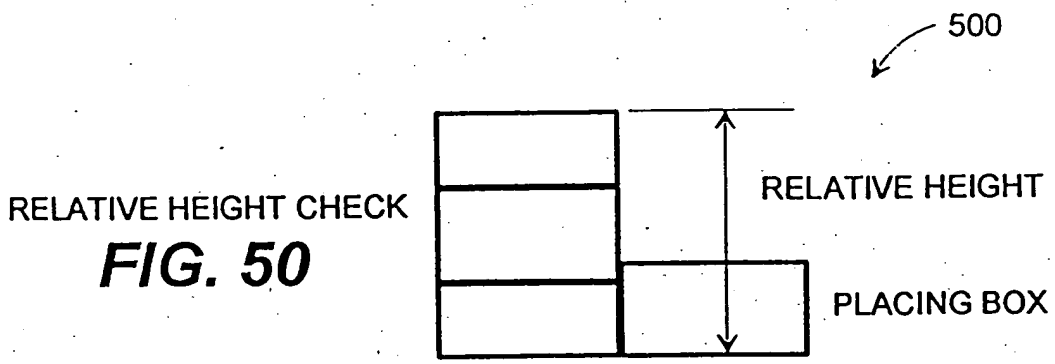
BOX 1 BOX 2 BOX 3 BOX 4

THE CORRESPONDING MATCHING HEIGHT COUNT FOR EACH BOX IS

1 0 1 0

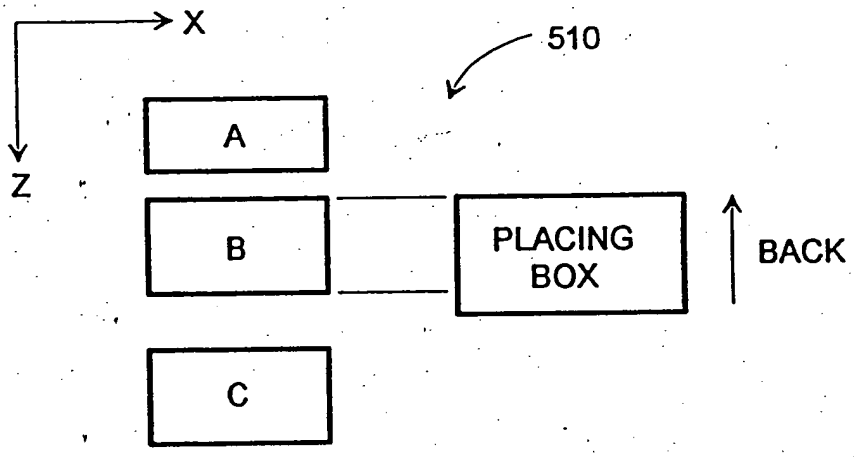
HEIGHT COUNT COMPUTATION

FIG. 49



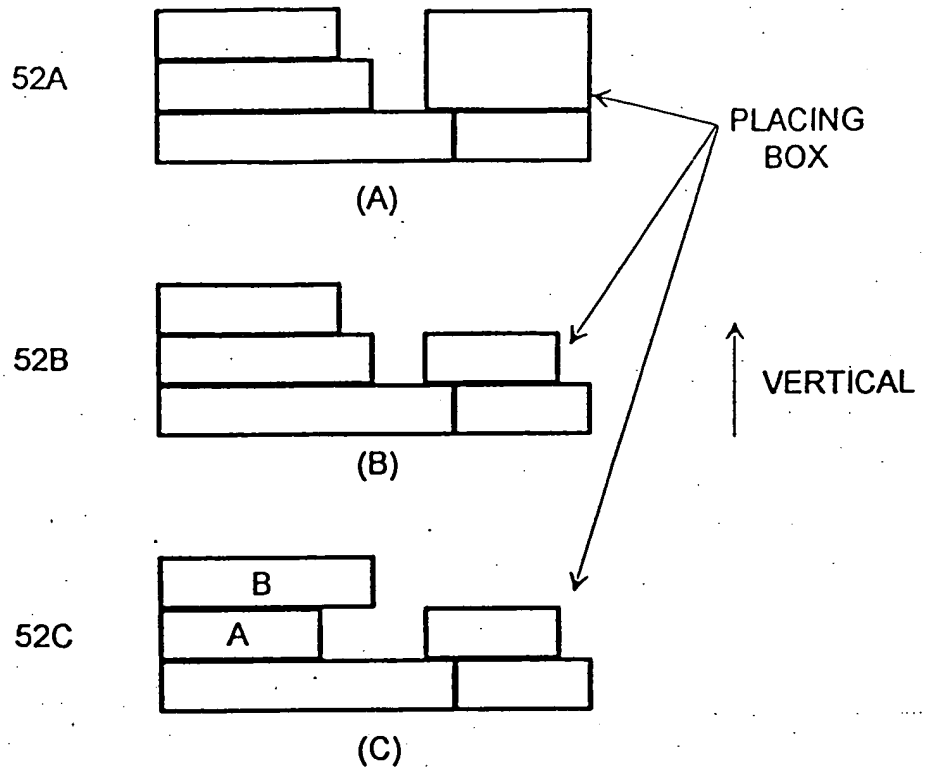
RELATIVE HEIGHT CHECK

FIG. 50



NEIGHBOR BOX HAS SIDE OVERLAP WITH PLACING BOX

FIG. 51



PLACING BOX LEVELS WITH NEIGHBOR

FIG. 52

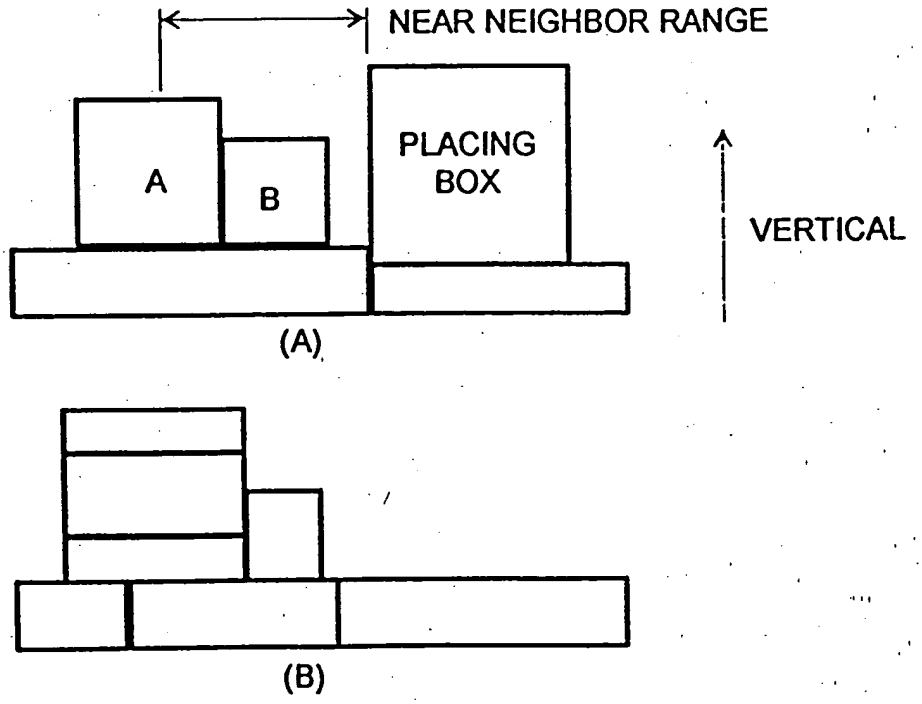


FIG. 53

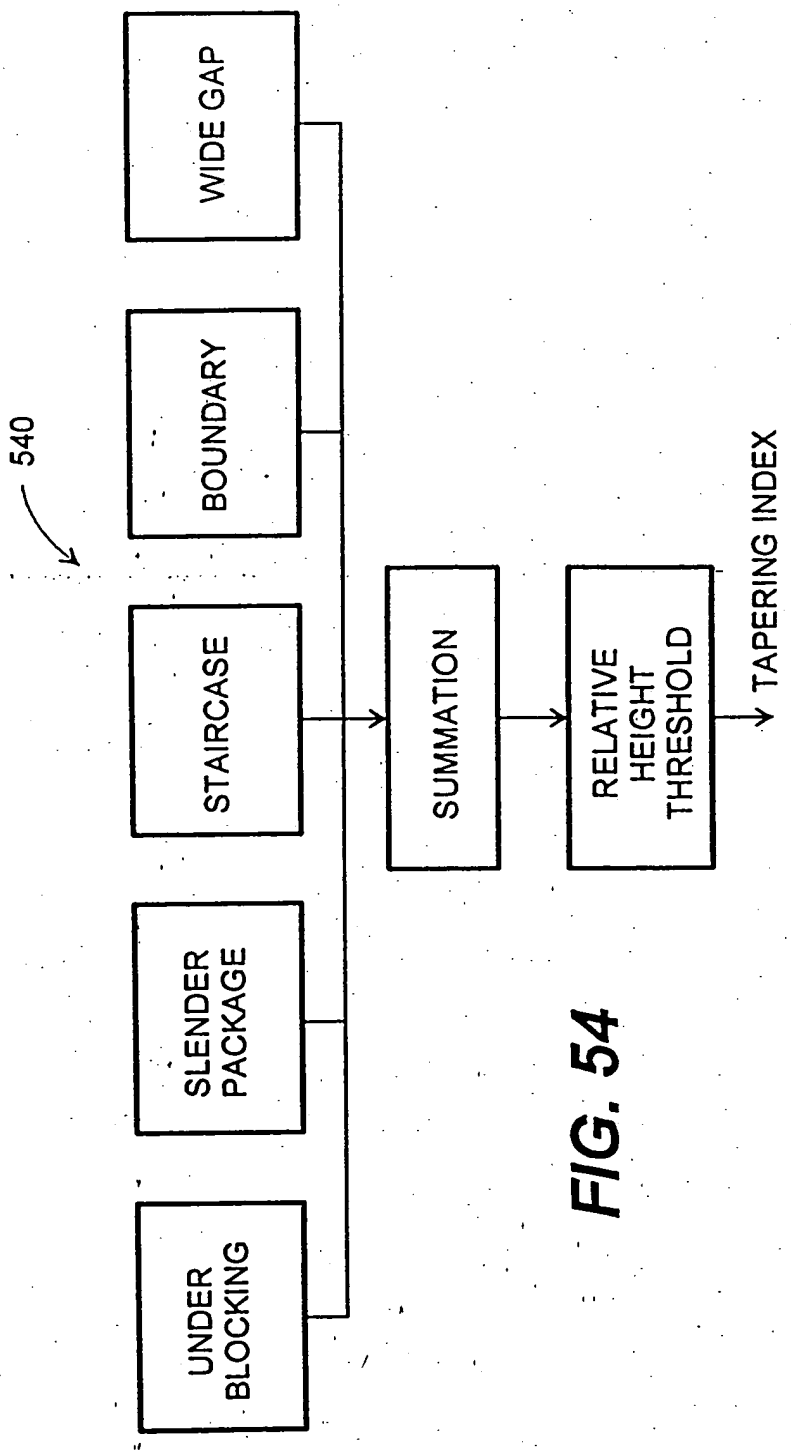

540
WIDE GAP
BOUNDARY
STAIRCASE
SLENDER PACKAGE
UNDER BLOCKING
SUMMATION
RELATIVE HEIGHT THRESHOLD
TAPERING INDEX

FIG. 54

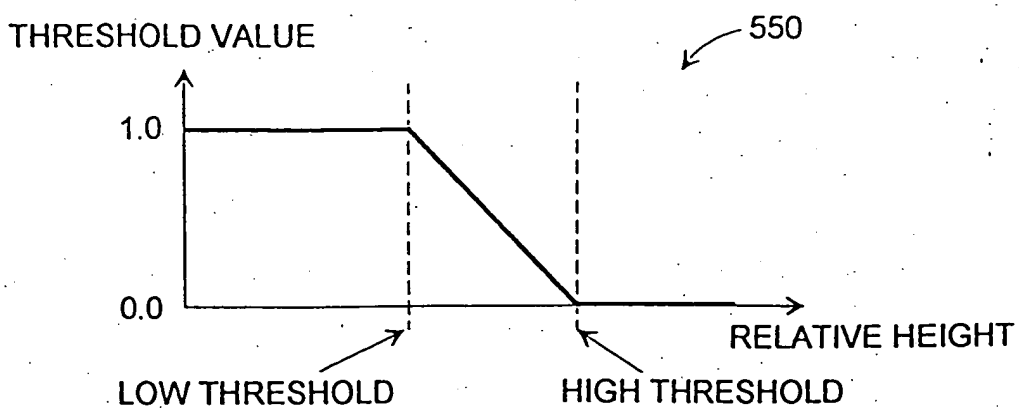
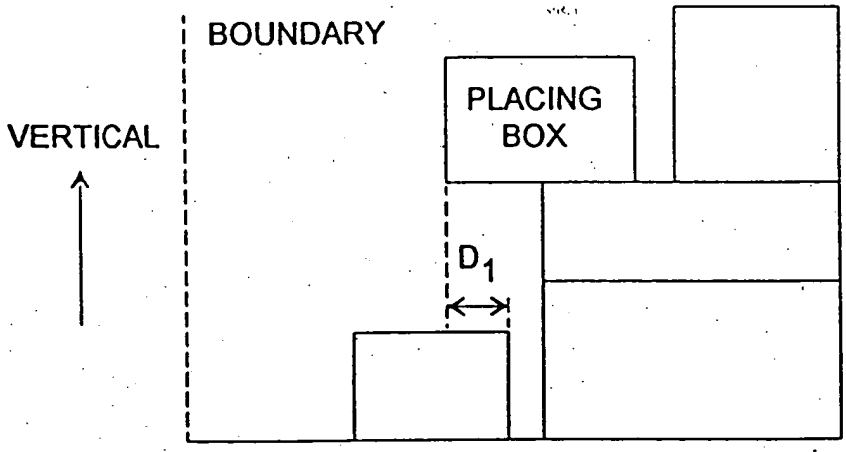


FIG. 55

BLOCK A LOWER :CORNER APPENDIX B:

RULE1: EXCESSIVEBLOCKING



W_A -AVERAGEWIDTH OF ALL BOXES IN STACK AND BUFFER

D_1 -MINIMUM BLOCKED HORIZONTAL LENGTH IN LOWER CORNER SURFACES

IF:

$D_1 > W_A / 3$

THEN:

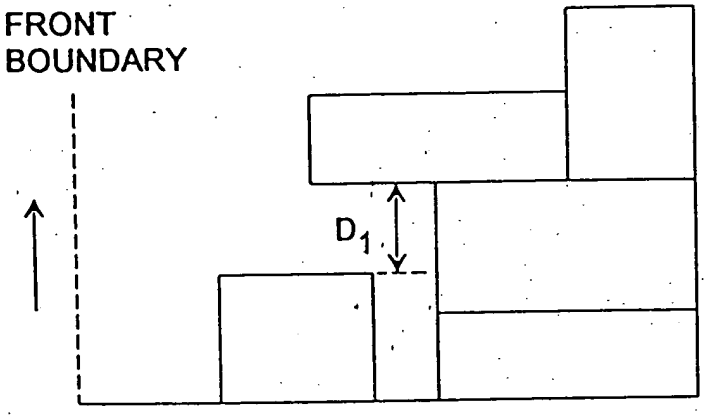
TAPERING INDEX: $D_1 / (W_A / 3)$

STACKING RULES

FIG. 56

BLOCK A LOWER CORNER:
RULE 2: BLOCK A POSSIBLE UNDER PLACEMENT

HA–AVERAGE HEIGHT OF ALL BOXES IN STACK AND BUFFER
W_M - MINIMUM WIDTH OF ALL BOXES IN BUFFER
W_A - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER
A_A - AVERAGE AREA OF ALL BOXES IN STACK AND BUFFER



IF:
BEFORE BOX IS PLACED:
IT IS POSSIBLE TO PLACE A BOX IN A LOWER CORNER
AND

$D_1 < 1.7H_A$ AND

AFTER BOX IS PLACED
MOST LIKELY IT IS NOT POSSIBLE TO PLACE BOX ON TOP OF UNDERSURFACE

THEN
TAPER INDEX 1

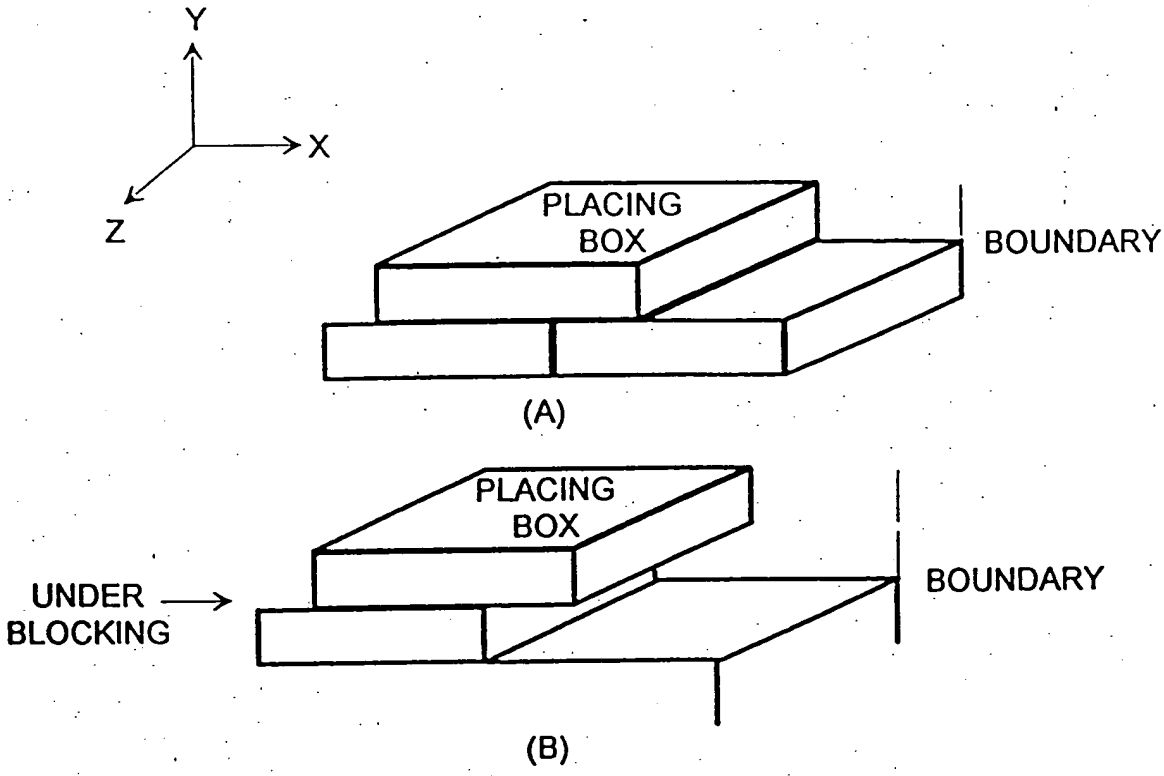
CONDITION FOR BEING MOST POSSIBLE TO PLACE A BOX IN A LOWER CORNER:
CORNER'S MIN. DIMENSION $\geq W_A$ AND
CORNER'S MIN. DIMENSION $\geq W_M$ AND
CORNER'S MIN. SURFACE DIMENSION > $06W_A$
AND CORNER'S SURFACE AREA > $0.6A_A$

CONDITION FOR BEING MOST LIKELY NOT POSSIBLE TO PLACE BOX IN LOWER CORNER AFTER PLACING BOX
CORNER'S UNBLOCKED MIN. DIMENSION < $0.9\ W_A$ OR
CORNER'S UNBLOCKED MIN. DIMENSION < W_M OR
CORNER'S UNBLOCKED MIN. SURFACE DIMENSION < $0.6\ W_A$ OR
CORNER'S UNCLOCKED SURFACE AREA < $0.6\ A_A$

D_1 –SHOULDER HEIGHT

STACKING RULES

FIG. 57

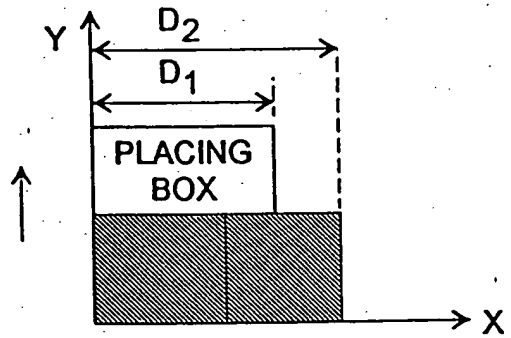


BOUNDARY CORNER CHECK

FIG. 58

SLENDER BOX:

RULE 3: SLENDER BOX AT CORNERSTONE



FRONTVIEW
(ALONG Z AXIS)

IF

BOX IS PLACED AT CORNERSTONE POSITION AND $D_1 < W_A$ AND $D_2 > W_A$

THEN

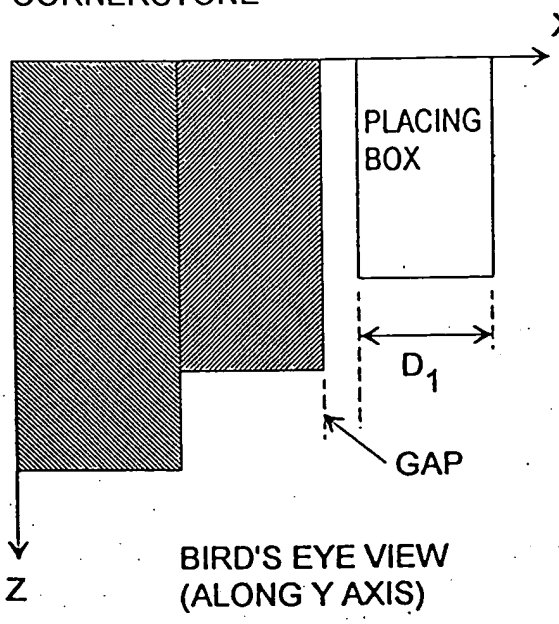
TAPERING INDEX: 2

W_A - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER
CORNERSTONE – VERY FIRST BOX INA NEW SHELF
D_1 – TOTAL WIDTH OF A LEVELING BOX GROUP
D_2 – SUPPORTING SURFACE SPAN

STACKING RULES

FIG. 59

SLENDER BOX:
RULE 4: A SLENDER BOX $_B$ IS POSITIONED AT LOCATIONS OTHER THAN CORNERSTONE



IF
D $< 0.7\ W_A$ AND
(PLACING BOX IS NOT LEVEL WITH ITS NEIGHBORS OR THE GAP $> W_A/3$) AND
THE SUPPORTING SURFACE IS WIDER THAN D AND THE PLACING BOX IS NOT NEAR TO THE OUTSIDE BOUNDARY

THEN
TAPER INDEX: $2 \times (1 - D_1 / W_A)$

W_A - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER
D_1 --WIDTH OF A POSSIBLE LEVELING BOX GROUP

STACKING RULES

FIG. 60

FIG. 61A

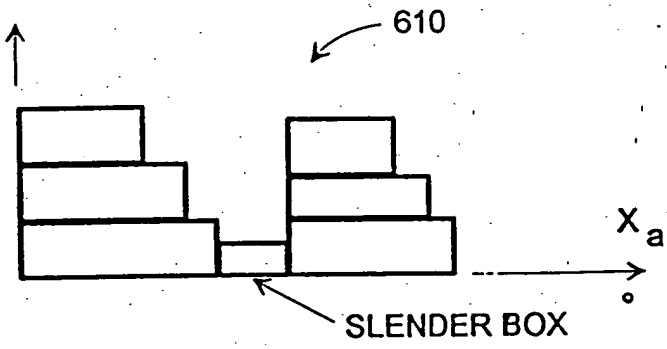
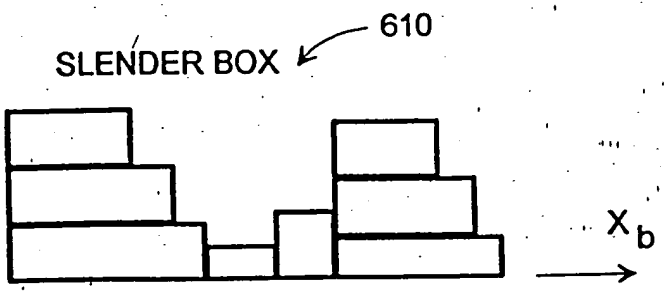
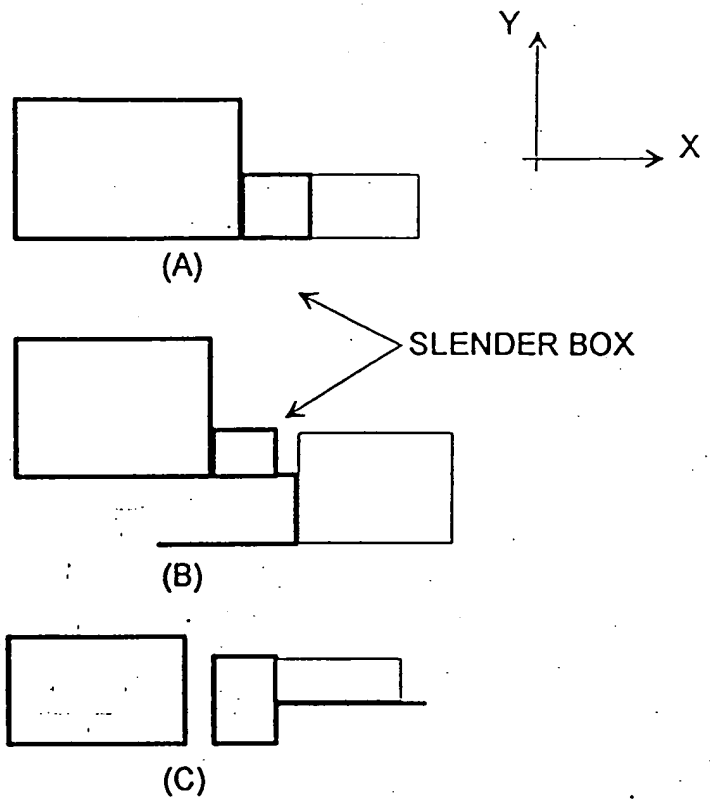


FIG. 61B





FIND A MATCHING BOX

FIG. 62

FIG. 63A

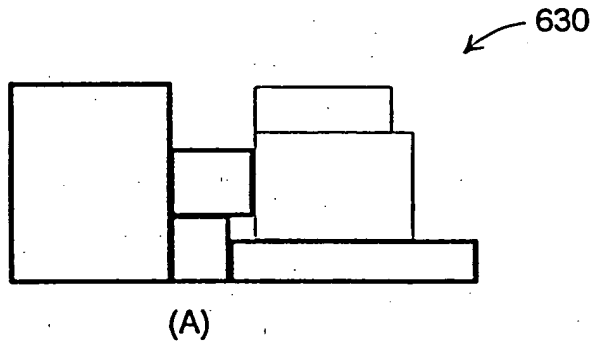
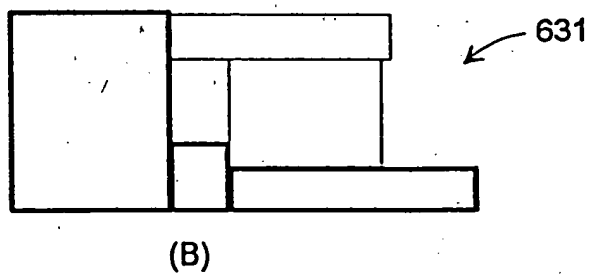
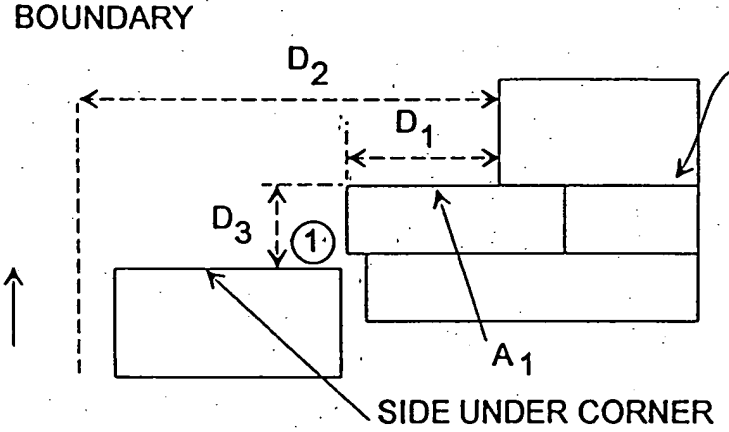


FIG. 63B



SLENDER BOX AMPLIFIES A GAP

STAIRCASE:
RULE 5: POTENTIAL STAIRCASE ON THE SIDE



IF:
$D_1 > W_A/3$ AND
($D_1 < 0.6W$ OR
$D_2 < W_M$) AND
$A_1 > A_A/5$ AND
A_1 IS WELL SUPPORTED

THEN
IF SIDE UNDER CORNER
IS NOT USEFUL
THEN
TAPERING INDEX: $D_1/(W_A/5)$
ELSE
OF $D_3 < H_M$
THEN
TAPERING INDEX:
$0.5xD_1/(W_A/5)$

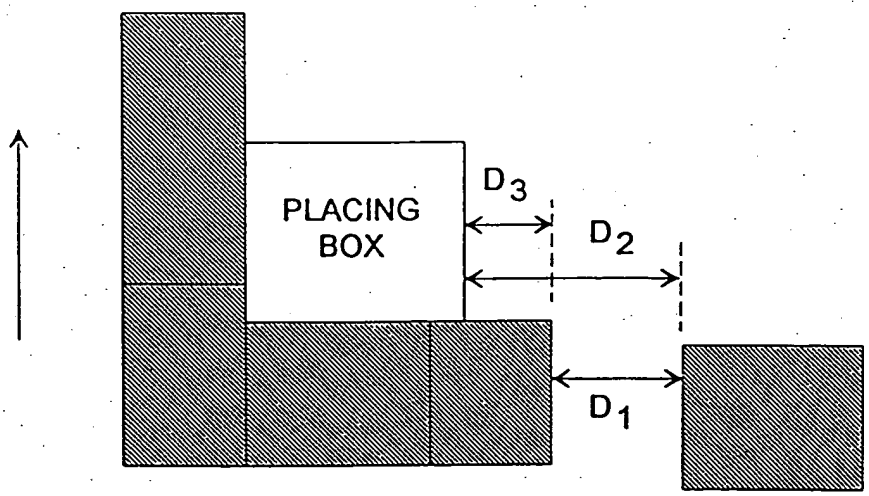
D_1 – MIN. SURFACE DIMENSION ON THE SIDE OF PLACING BOX
D_2 – MIN. REMAINING CORNER DIMENSION
D_3 – RELATIVE SHOULDER HEIGHT
A_1 – REMAINING SURFACE
W_A –AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER
W_M – MINIMUM WIDTH OF ALL BOXES IN BUFFER
H_M – MINIMUM HEIGHT OF ALL BOXES IN BUFFER
A_A – AVERAGE AREA OF ALL BOXES IN STACK AND BUFFER

STACKING RULES

FIG. 64

STAIRCASE:

RULE 6: THERE EXISTS A BIG GAP INTHE MIDDLE OF A NEARBY CORNER SURFACES AND CURRENT PLACEMENT LEAVES USELESS SPACE ON THE SAME SIDE



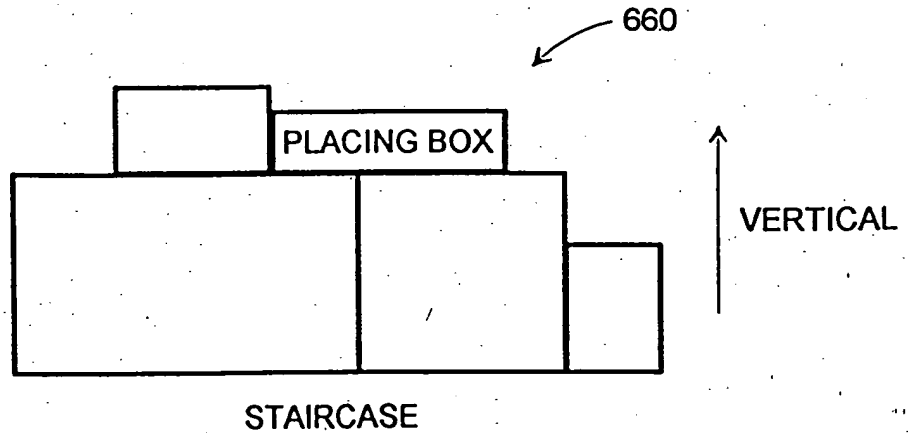
IF
$D_1 < W_A$ AND
$D_1 > W_A/2$ AND
$D_2 > 0.7\ W_A$ AND
$D_3 >$ 1" AND
$D_3 < W_A/2$

THEN
TAPERING INDEX:
$D_3 / (W_A/3)$

D_1 -- GAP IN CORNER SURFACE ON THE SIDE
D_2 -- DISTANCE TO NEXT CORNER SURFACE
D_3 -- MIN. DIMENSION OF REMAINING SURFACE
W_A -- AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER

STACKING RULES

FIG. 65

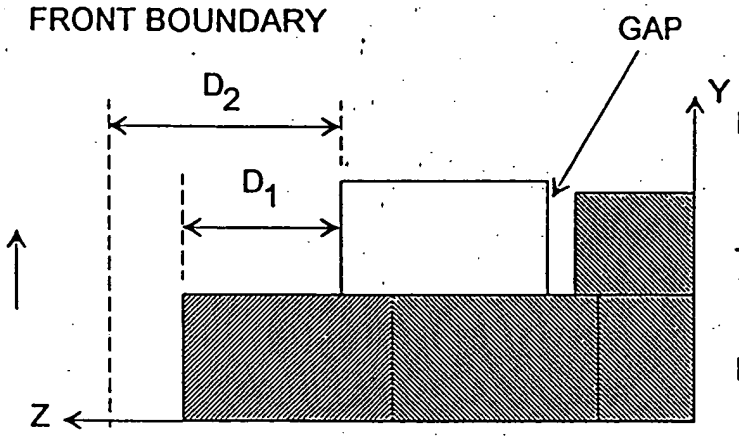


STAIRCASE

FIG. 66

670

BOUNDARY:
RULE 7: LEAVE POTENTIALLY UNUSABLE SPACE ON FRONT BOUNDARY



RIGHT SIDE VIEW
(ALONG X AXIS)

IF
$D_1 > W_A /3$ AND
$D_2 < W_A$

THEN
TAPERING_INDEX: 1

IF IN ADDITION THE GAP
$> W_A /3$ OR
THE PLACING BOX IS NOT LEVEL WITH NEIGHBORING BOXES

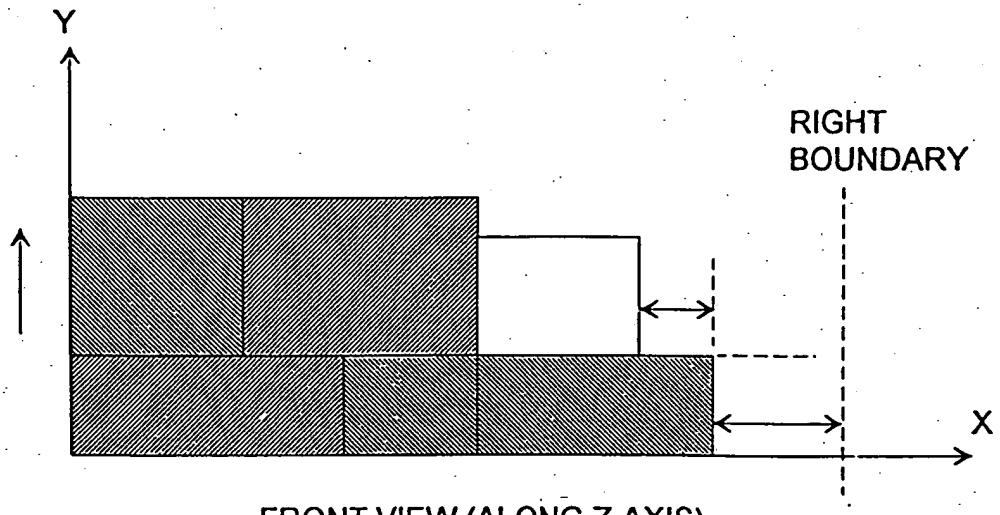
THEN
TAPERING_INDEX: $1.1D_1 /W_A = 1.1(D_1 /W_A)$

D_1 – MIN. DIMENSION ON REMAINING SURFACES
D_2 – DISTANCE TO FRONT BOUNDARY
W_A - AVERAGE WIDTH OF ALL BOZES IN STACK AND BUFFER

STACKING RULES

FIG. 67

BOUNDARY:
RULE 8: TOO MUCH SURFACE SPACE COULD BECOME WASTEFUL ON RIGHT BOUNDARY



FRONT VIEW (ALONG Z AXIS)

IF
*BOX IS CLOSE TO RIGHT BOUNDARY AND
NO BOX CAN BE PLACED ON THE RIGHT OF
PLACING BOX TO MATCH ITS HEIGHT AND
$D_1 > W_A/3$

THEN
TAPERING INDEX: $1.7 \times D_1 / W_A / 3$

*BOX IS CONSIDERED AS CLOSE TO RIGHT BOUNDARY WHEN

$D_2 < L_A$ OR
($D_2 < 1.5\ L_A$ AND
$D_1 < L_A$ AND
THE LOWER CORNER ASSOCIATED WITH D_2
IS NOT USEFUL)

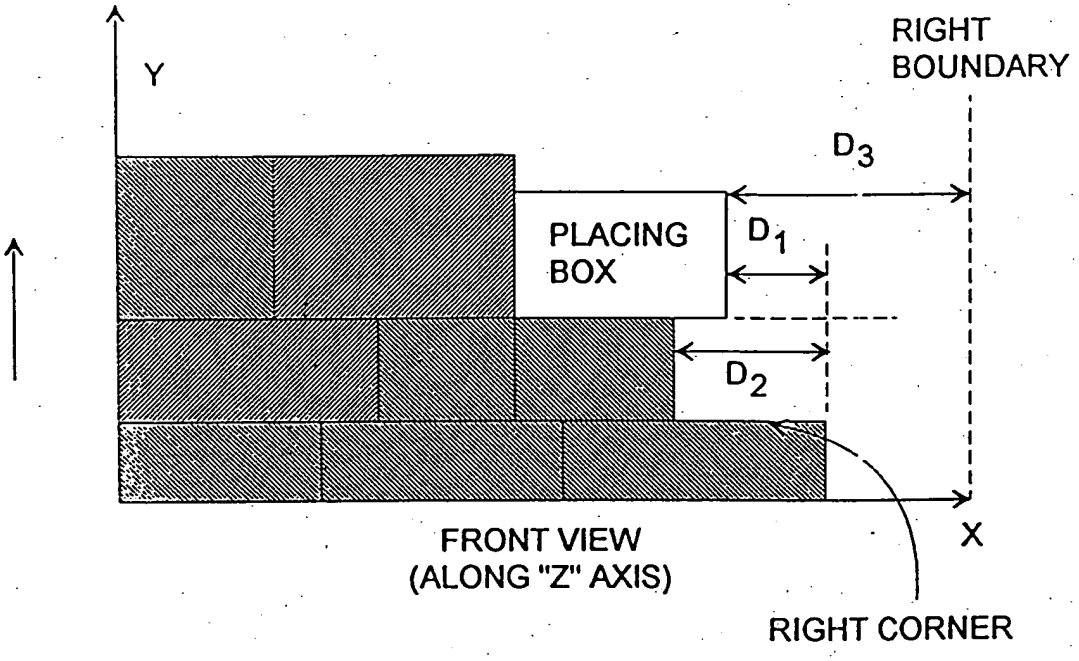
D_1 IS THE MINIMUM DIMENSION OF SURFACE AFTER PLACING BOX
D_2 – DISTANCE TO RIGHT BOUNDARY
L_A - AVERAGE LENGTH OF ALL BOXES IN STACK AND BUFFER

STACKING RULES

FIG. 68

BOUNDARY:

RULE 9: BLOCKING RIGHT CORNER AT BOUNDARY SO A POSSIBLE SIDE PLACEMENT MAY BE LOST



IF

*PLACING BOX IS CLOSE TO RIGHT BOUNDARY
AND
NO BOX CAN BE PLACED ON THE RIGHT OF PLACING BOX $_B$ TO MATCH ITS HEIGHT AND
$D_1 > 0.4\ W_A$ AND
RIGHT CORNER MAY BE USEFUL AND
$D_2 > 0.75\ W_A$

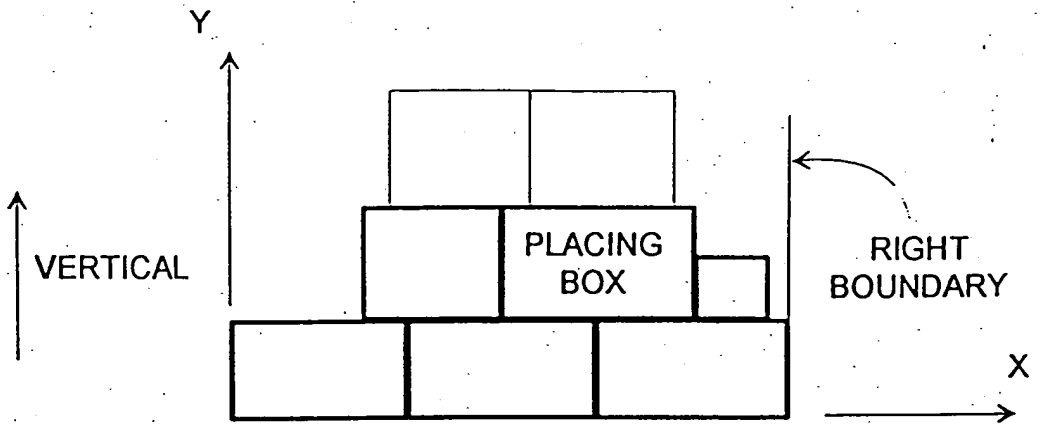
THEN

TAPERING INDEX: 1.5

D_1 -- MIN. DIMENSION OF UNBLOCKED SURFACE PORTION AT RIGHT CORNER
D_2 -- MIN. SURFACE DIMENSION OF RIGHT CORNER
D_3 -- DISTANCE TO RIGHT BOUNDARY

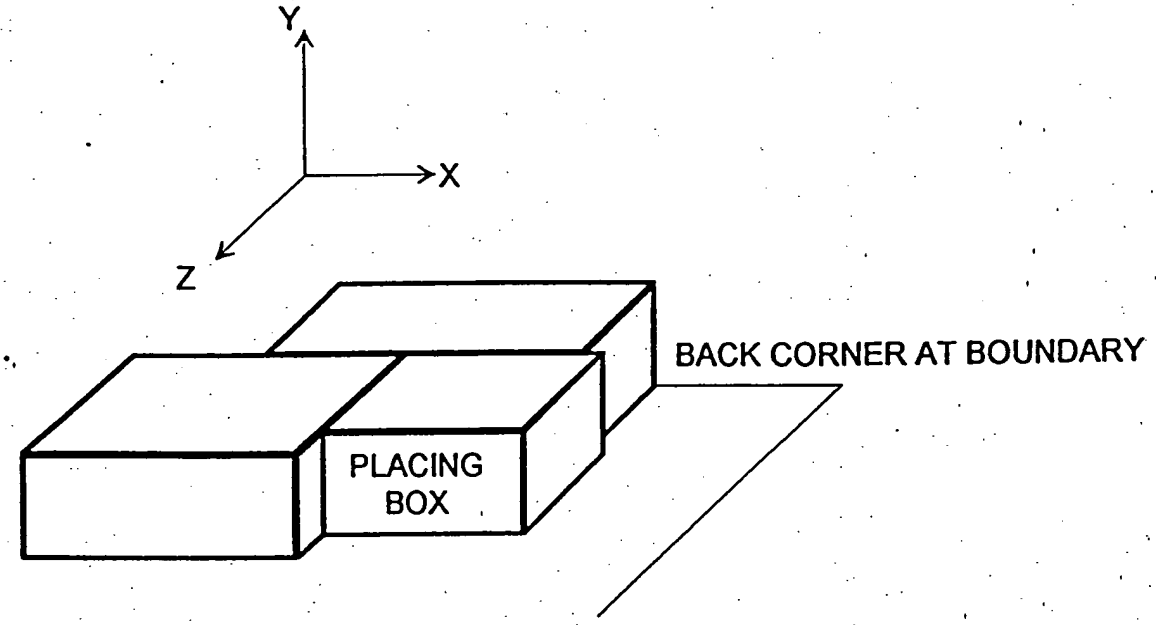
*PLACING BOX IS CLOSE TO RIGHT BOUNDARY WHEN $D_3 < L_A$
W_A - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER
L_A - AVERAGE LENGTH OF ALL BOXES INSTACK AND BUFFER

FIG. 69



UNRECOVERABLE RIGHT BOUNDARY
(VIEWED ALONG Z AXIS)

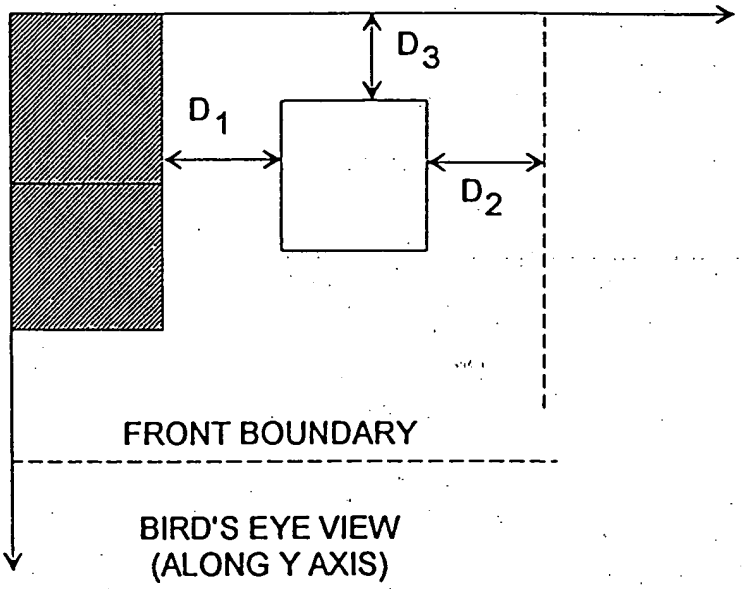
FIG. 70



BACK CORNER AT BOUNDARY

FIG. 71

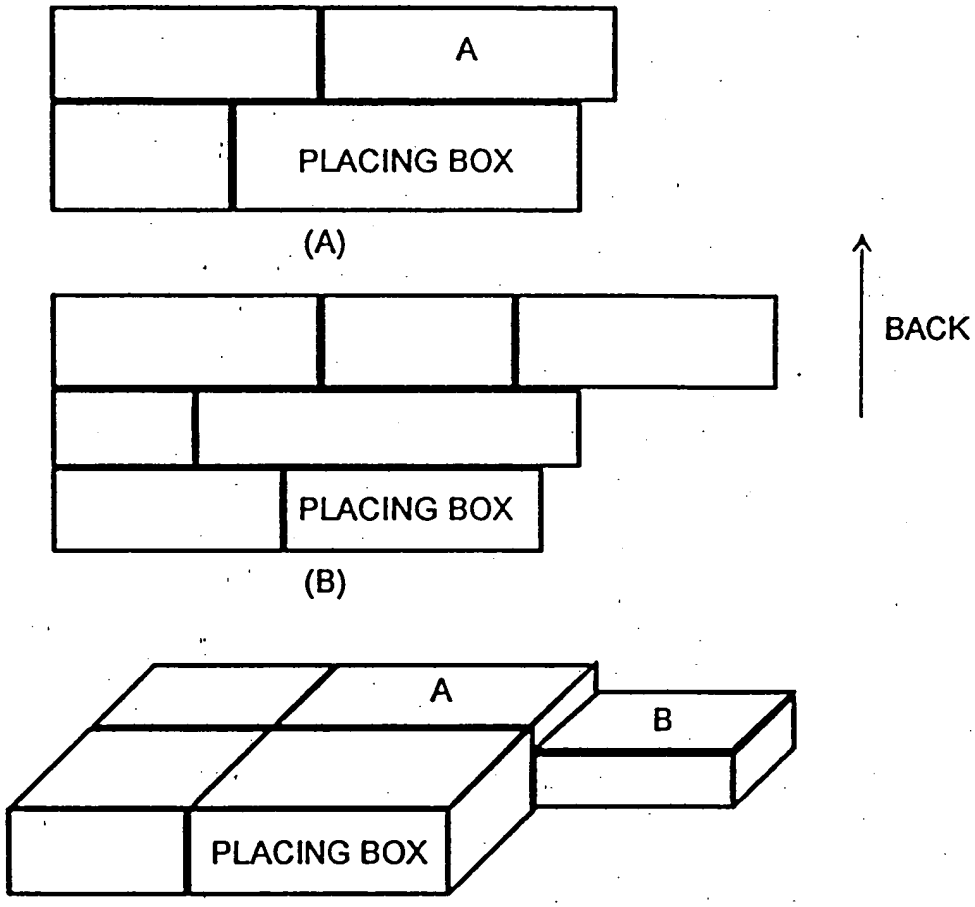
WIDE GAP
RULE 10: EXCESSIVE WIDE GAP WHEN PLACING BOX IS NOT NEAR THE FRONT BOUNDARY



D_1 – DISTANCE TO LEFT NEIGHBOR
D_2 – DISTANCE TO RIGHT CORNER BOUNDARY
D_3 – DISTANCE TO BACK CORNER BOUNDARY
W_A - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER
MIN(D_1 , D_2)– THE LESSER OF D_1 AND D_2

STACKING RULES

FIG. 72



BACK ALIGNMENT

FIG. 73

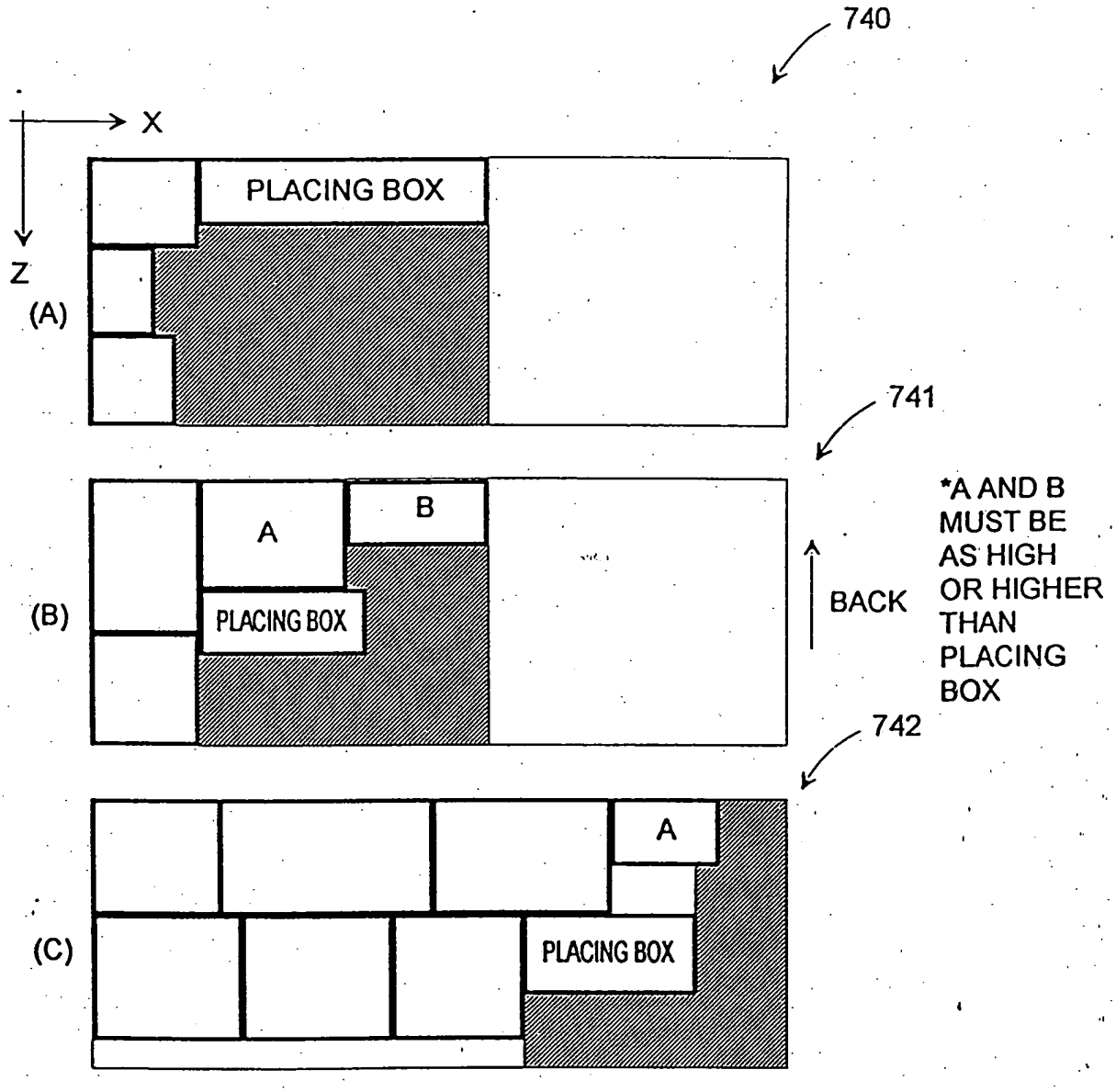

740
X
Z
(A)
PLACING BOX
741
(B)
A
B
PLACING BOX
BACK
*A AND B MUST BE AS HIGH OR HIGHER THAN PLACING BOX
742
(C)
A
PLACING BOX
BOX GROUP BOUNDARY

FIG. 74

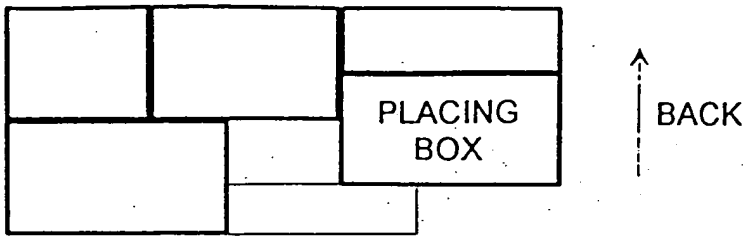
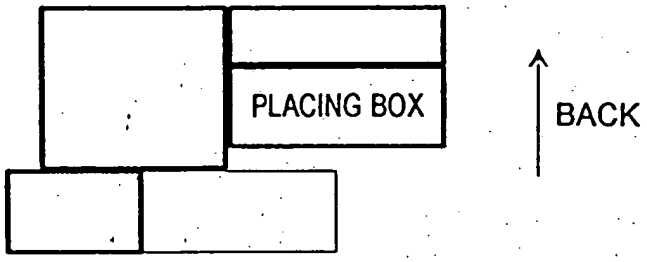


FIG. 75



SIDE FRONT CORNER FIT

FIG. 76

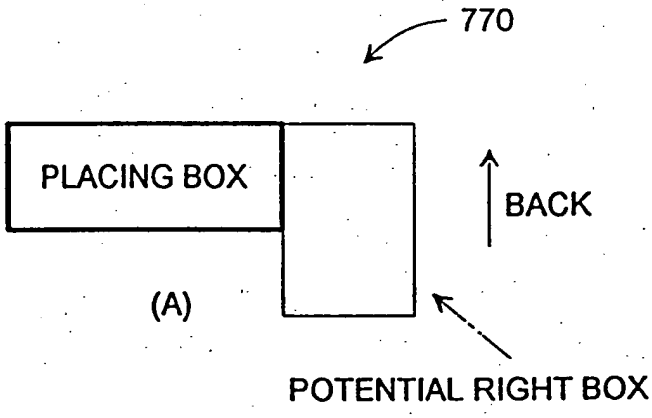


FIG. 77

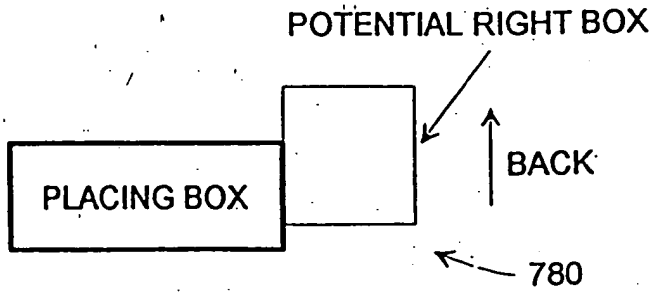
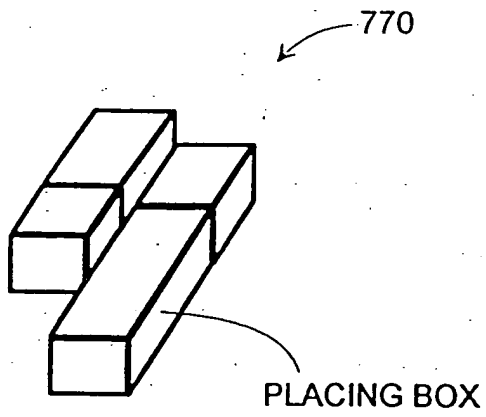


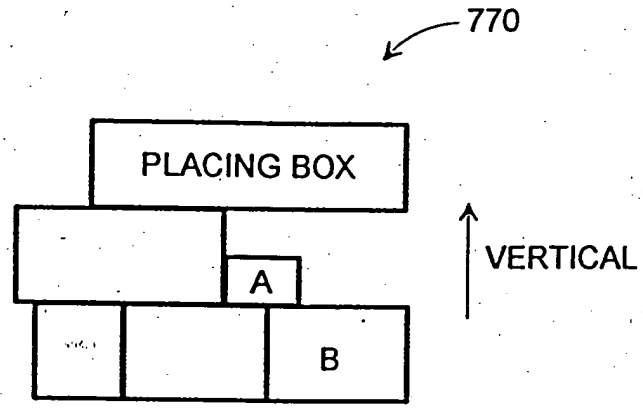
FIG. 78

(B)
POTENTIAL RIGHT PLACEMENT



BOX OVEREXTENDS BEYOND SIDE NEIGHBORS

FIG. 79



BLOCK LOW CORNERS

FIG. 80

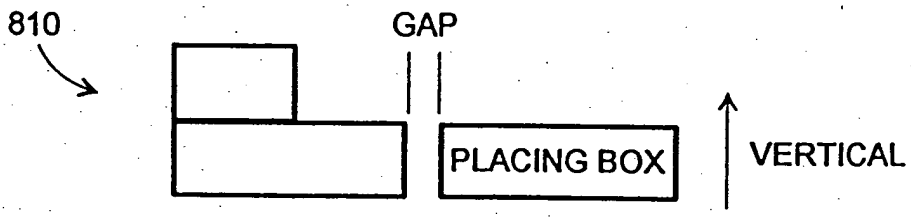
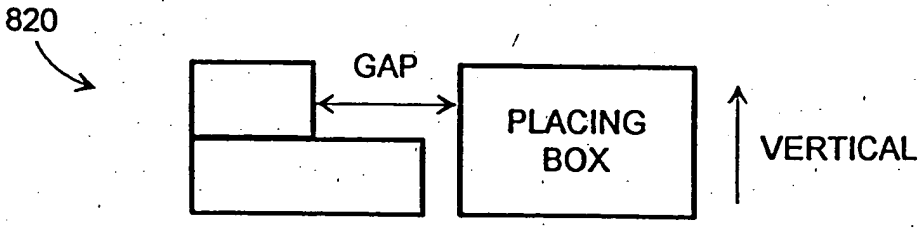


FIG. 81



GAP TO NEIGHBOR BOX

FIG. 82

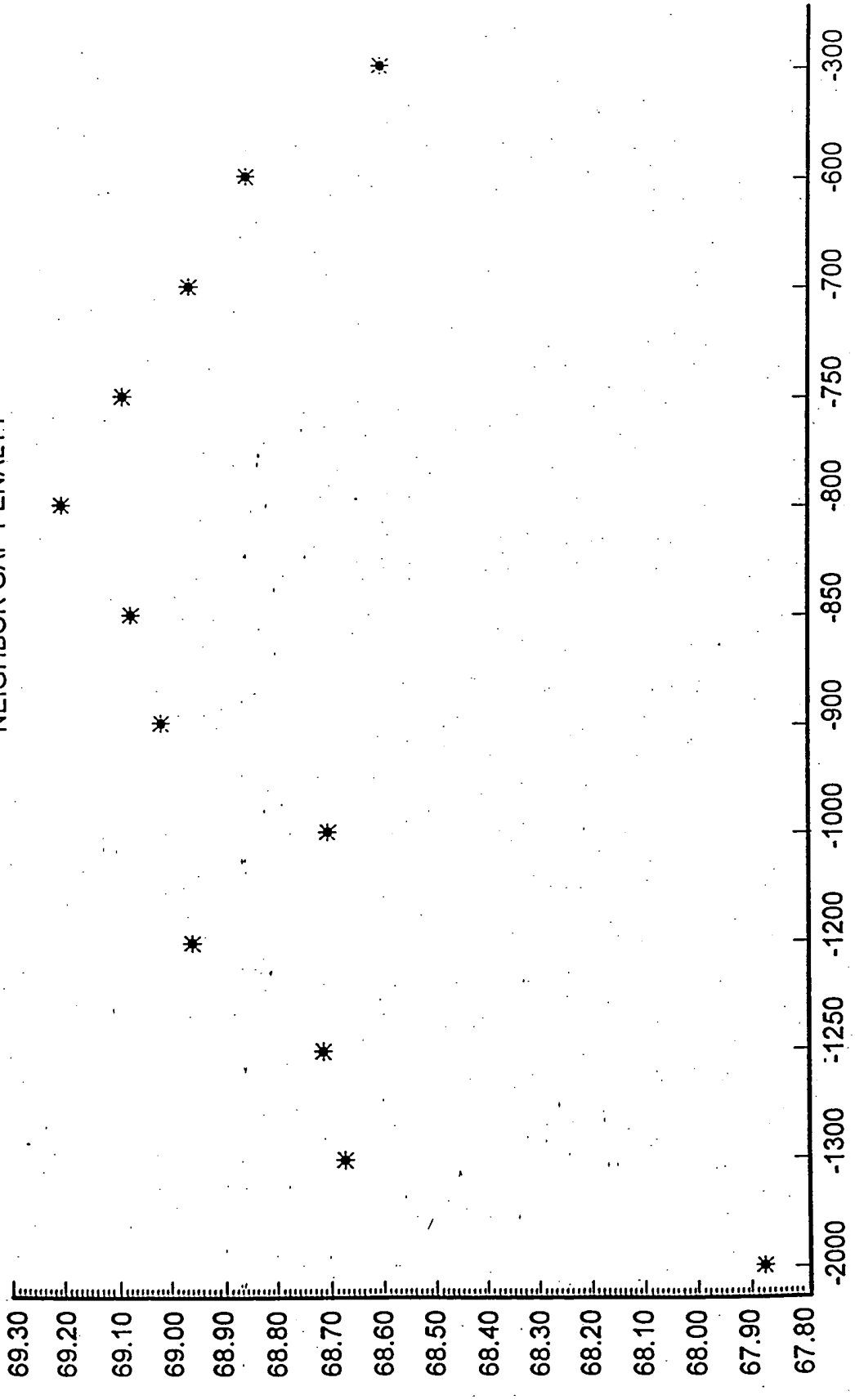
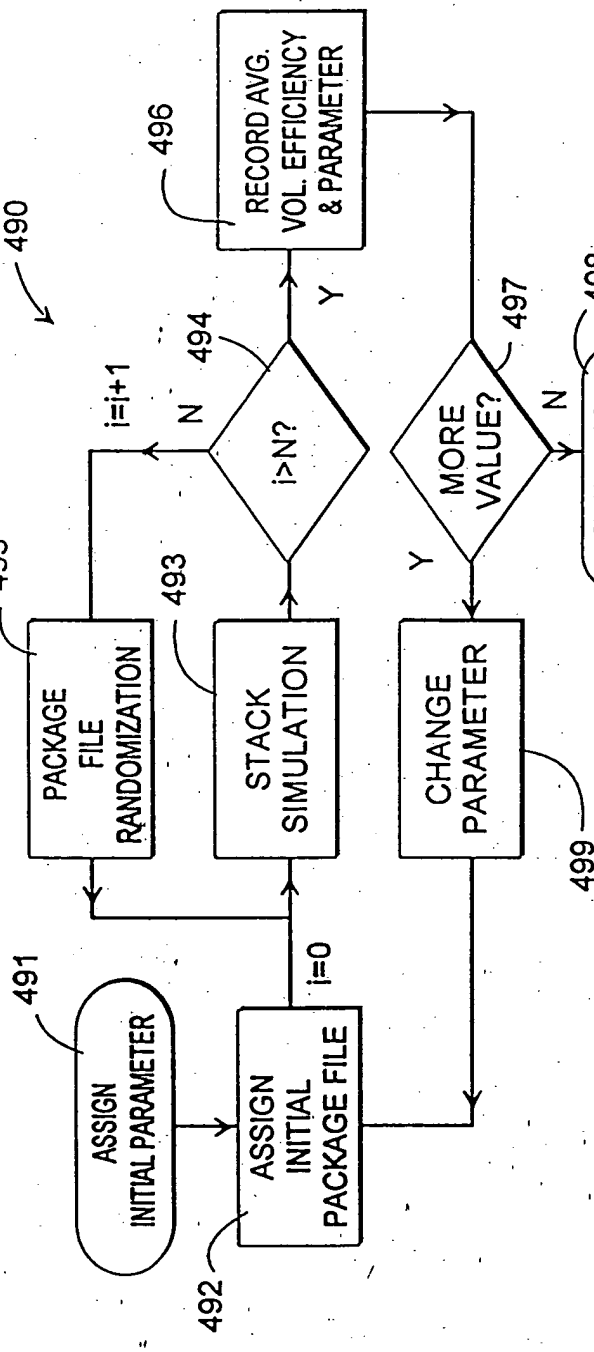

NEIGHBOR GAP PENALTY
-300
-600
-700
-750
-800
-850
-900
-1000
-1200
-1250
-1300
-2000
69.30
69.20
69.10
69.00
68.90
68.80
68.70
68.60
68.50
68.40
68.30
68.20
68.10
68.00
67.90
67.80

FIG. 83



AVERAGE VOLUME EFFICIENCY BASED PARAMETER SEARCH

FIG. 84

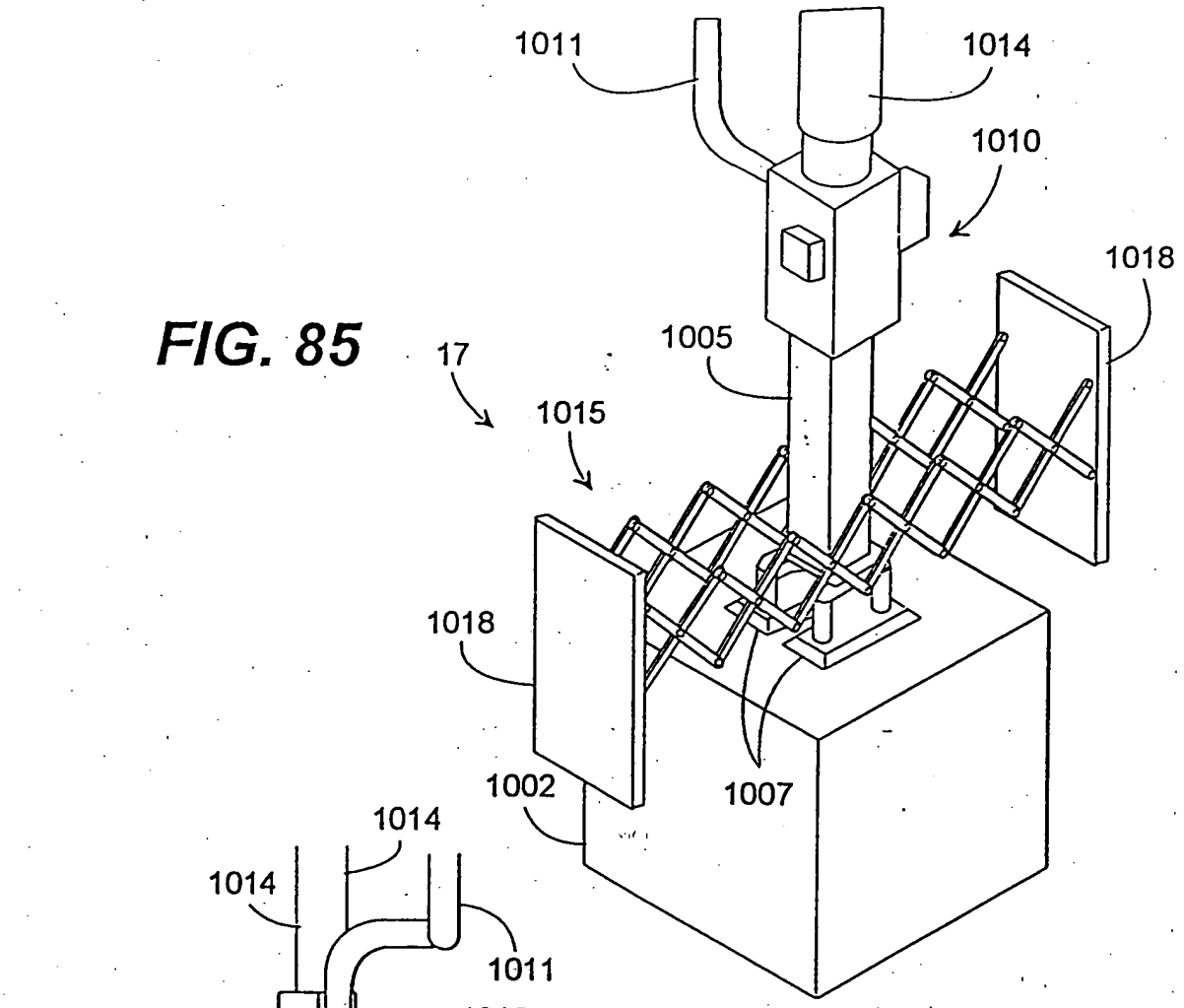

1011
1014
1010
1018
1005
17
1015
1018
1002
1007

FIG. 85

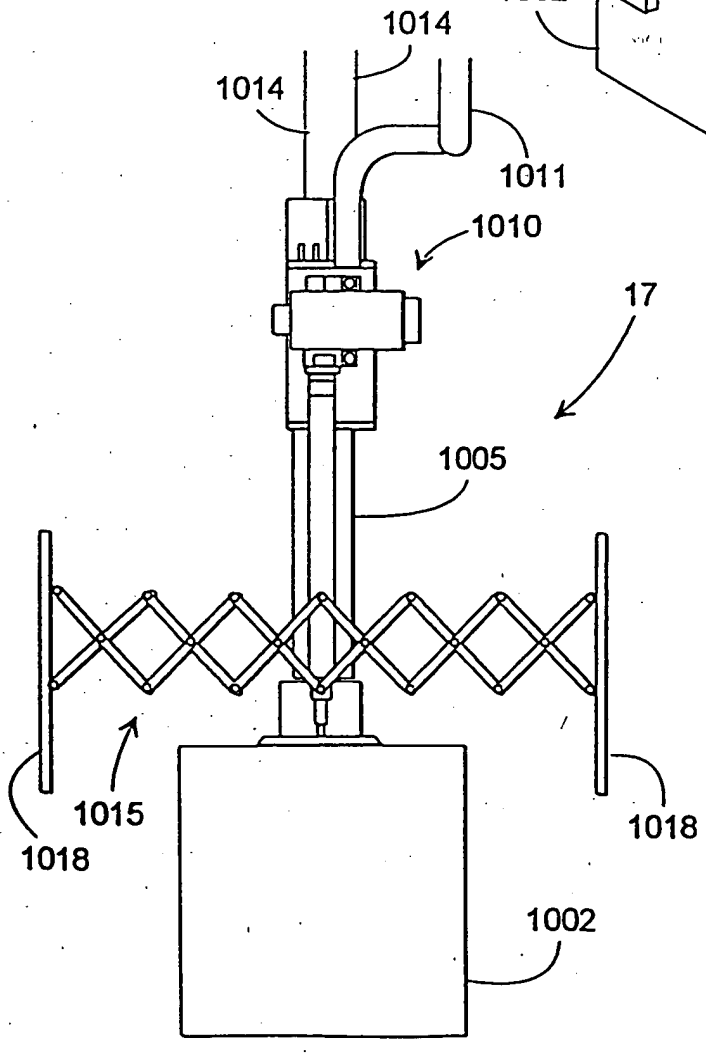

1014
1014
1011
1010
17
1005
1015
1018
1018
1002

FIG. 86

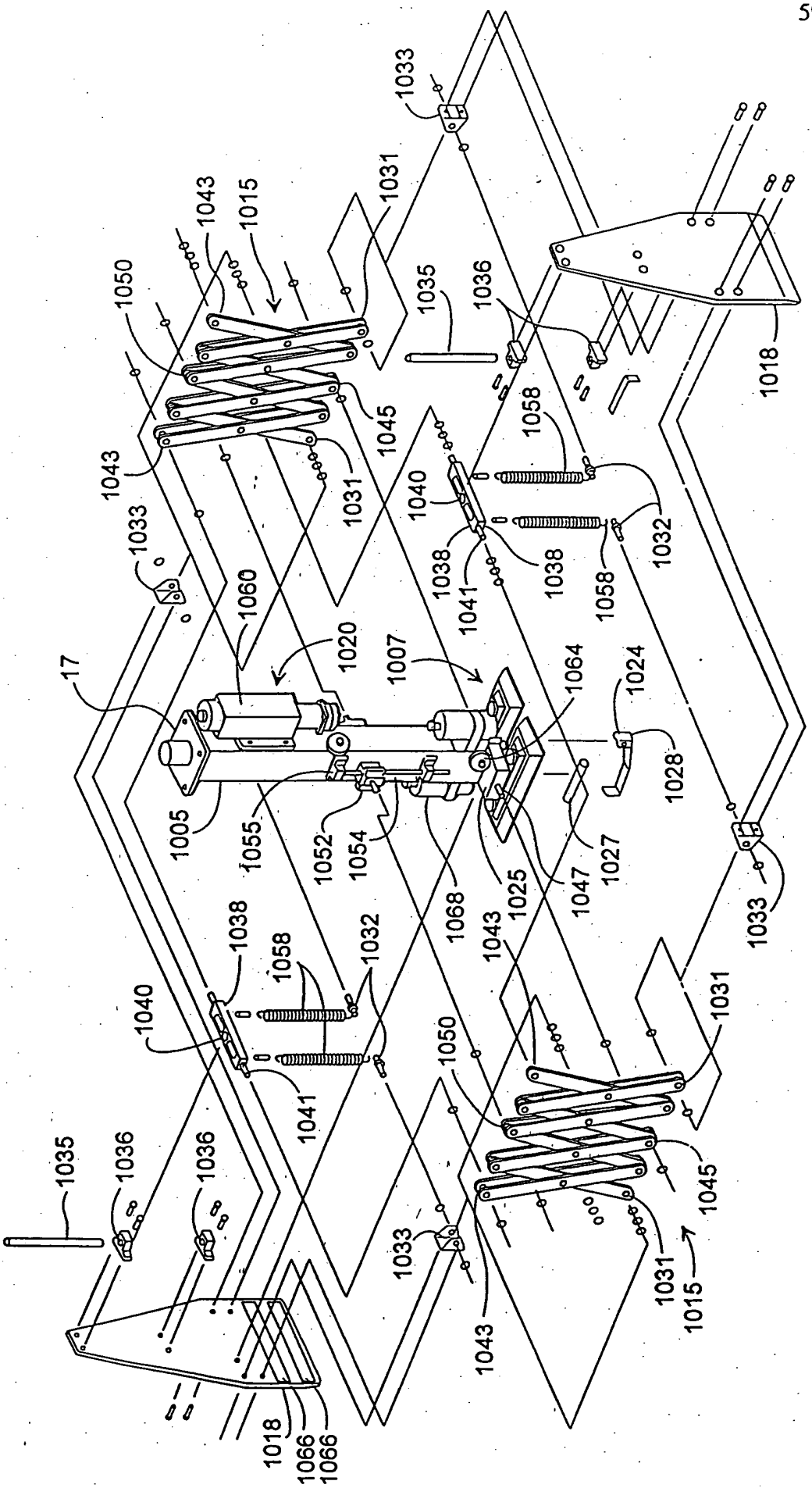

1033
1043
1015
1031
1050
1035
1036
1018
1045
1058
1040
1038
1041
1032
1060
1020
1007
17
1064
1024
1028
1005
1055
1052
1054
1027
1047
1025
1068
1066

FIG. 87

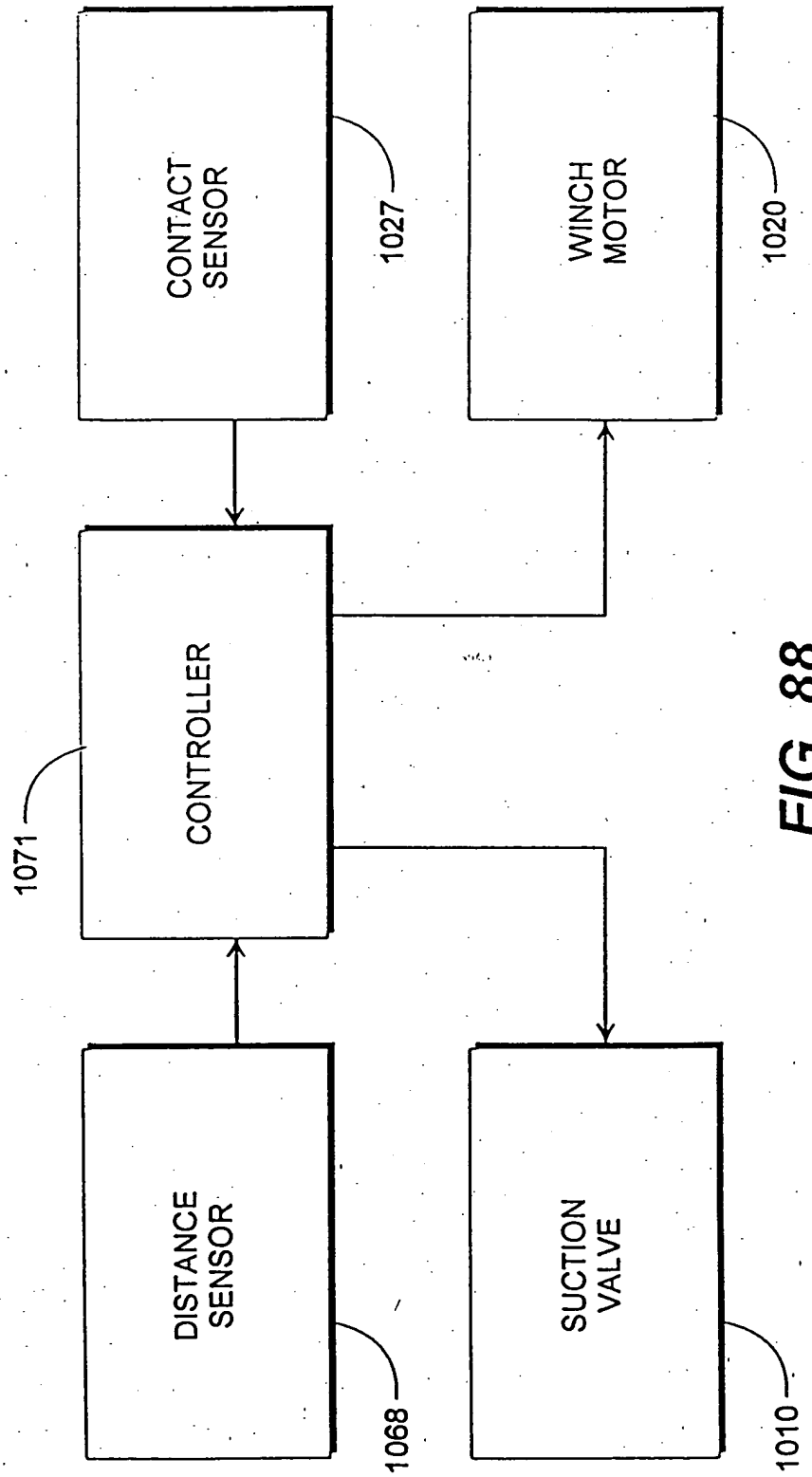

CONTACT SENSOR
1027
WINCH MOTOR
1020
CONTROLLER
1071
DISTANCE SENSOR
1068
SUCTION VALVE
1010

FIG. 88

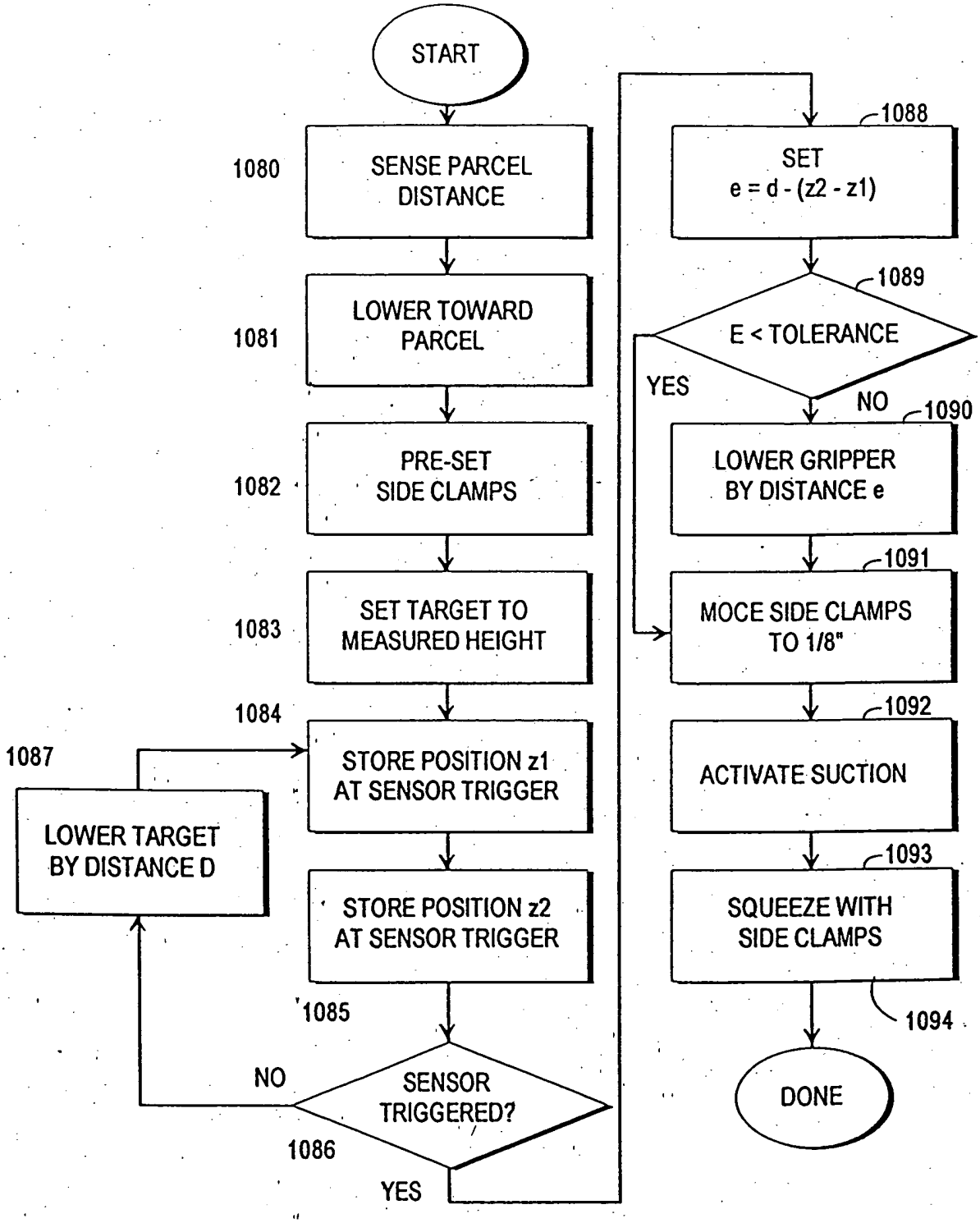

START
1080
SENSE PARCEL DISTANCE
1081
LOWER TOWARD PARCEL
1082
PRE-SET SIDE CLAMPS
1083
SET TARGET TO MEASURED HEIGHT
1084
STORE POSITION z1 AT SENSOR TRIGGER
1087
LOWER TARGET BY DISTANCE D
STORE POSITION z2 AT SENSOR TRIGGER
1085
NO
SENSOR TRIGGERED?
1086
YES
1088
SET e = d - (z2 - z1)
1089
E < TOLERANCE
YES
NO
1090
LOWER GRIPPER BY DISTANCE e
1091
MOCE SIDE CLAMPS TO 1/8"
1092
ACTIVATE SUCTION
1093
SQUEEZE WITH SIDE CLAMPS
1094
DONE

FIG. 89

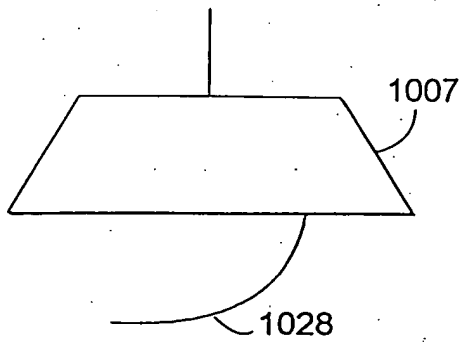


FIG. 90

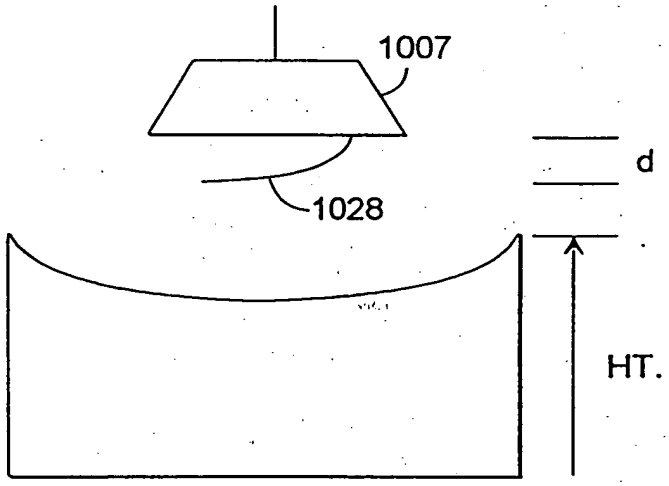


FIG. 91A

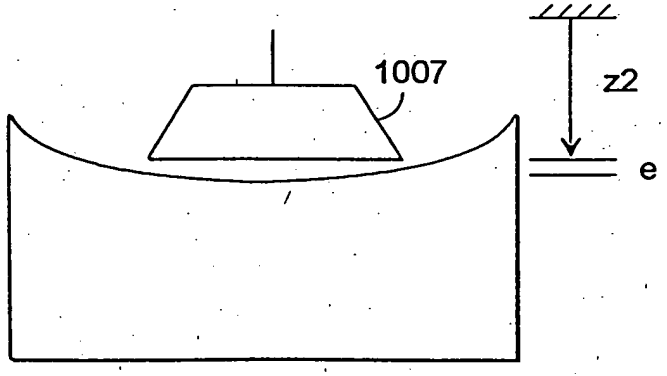


FIG. 91B

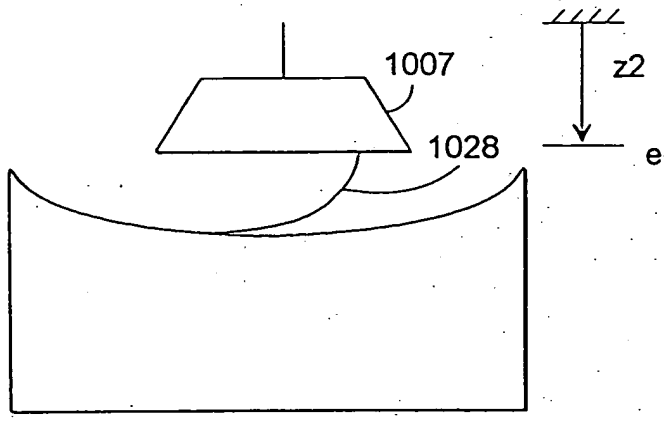


FIG. 91C

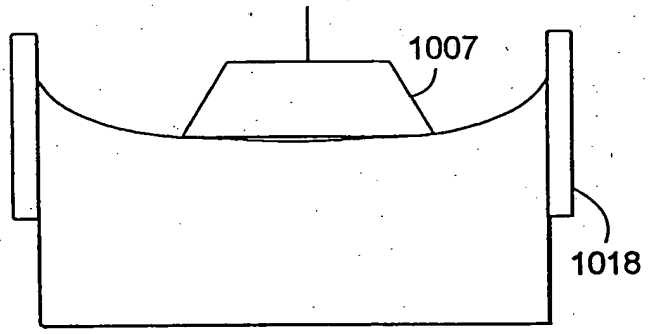


FIG. 91D

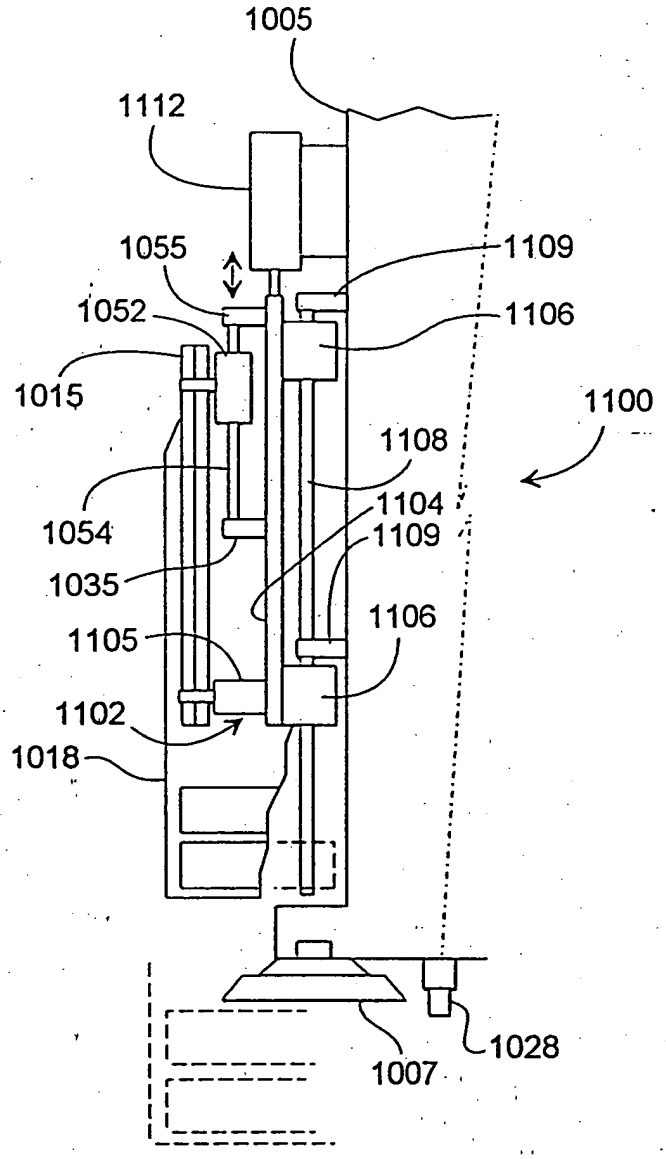

1005
1112
1055
1109
1052
1106
1015
1100
1108
1104
1054
1109
1035
1106
1105
1102
1018
1028
1007

FIG. 92

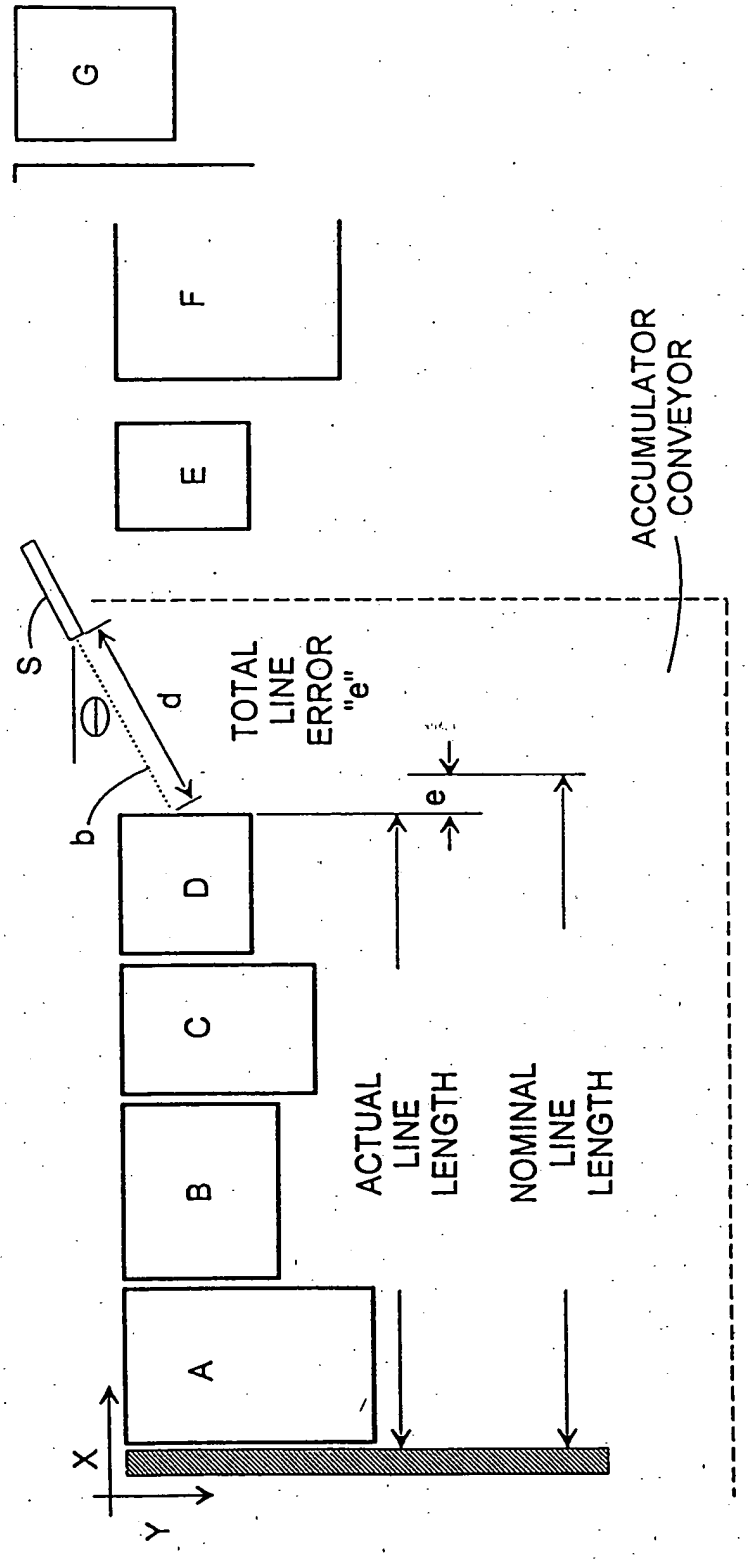

G
F
E
D
C
B
A
S
b
d
θ
e
TOTAL LINE ERROR "e"
ACTUAL LINE LENGTH
NOMINAL LINE LENGTH
ACCUMULATOR CONVEYOR
X
Y

FIG. 93

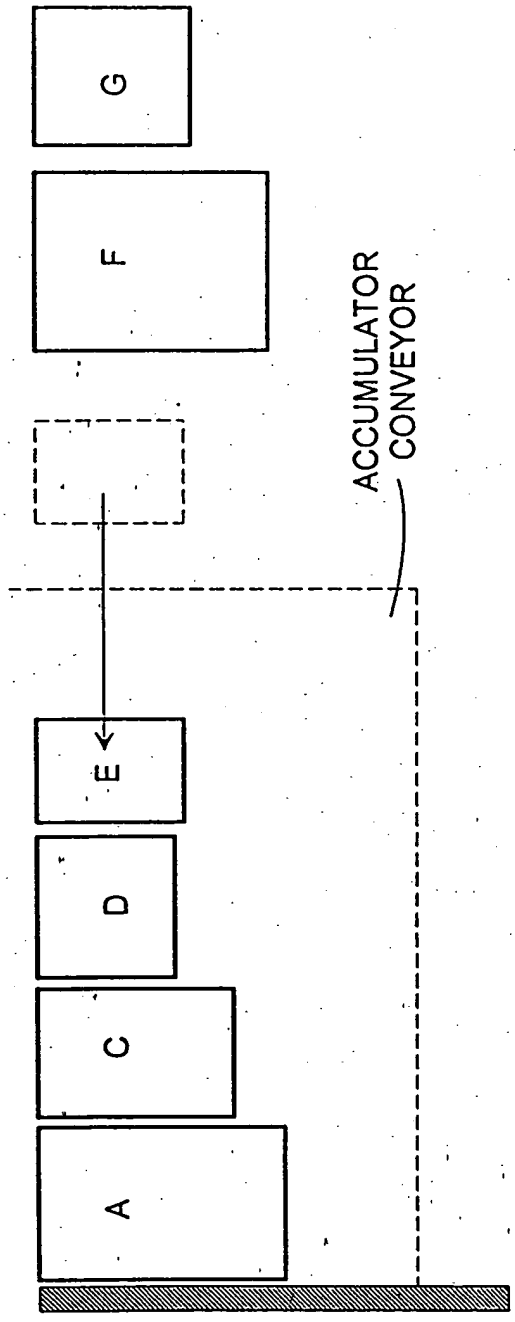


FIG. 94

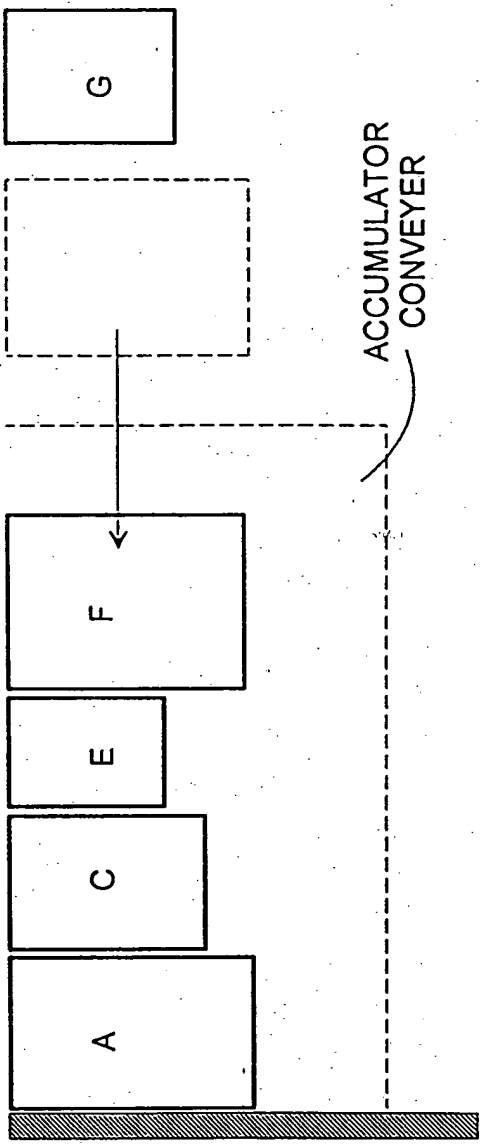


FIG. 95

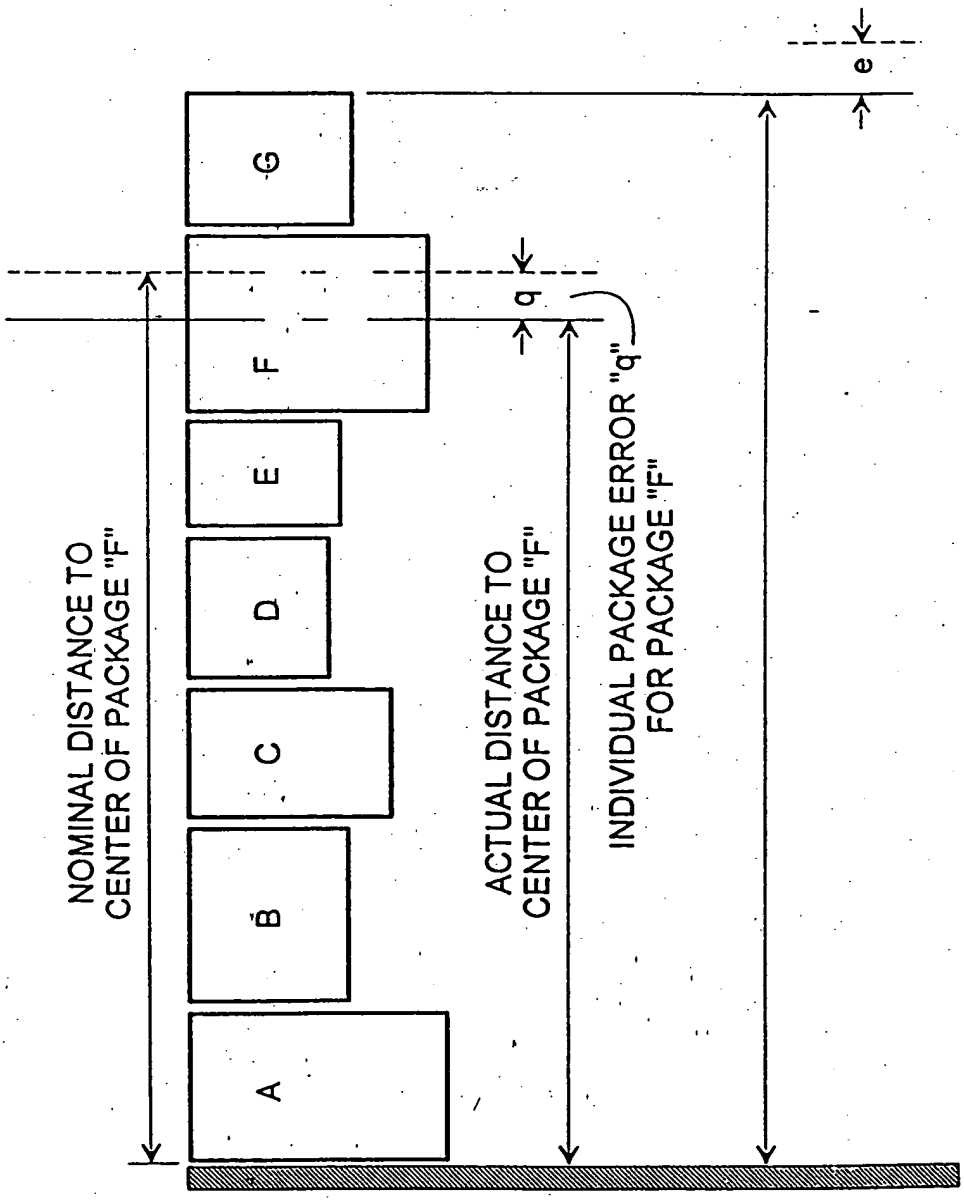
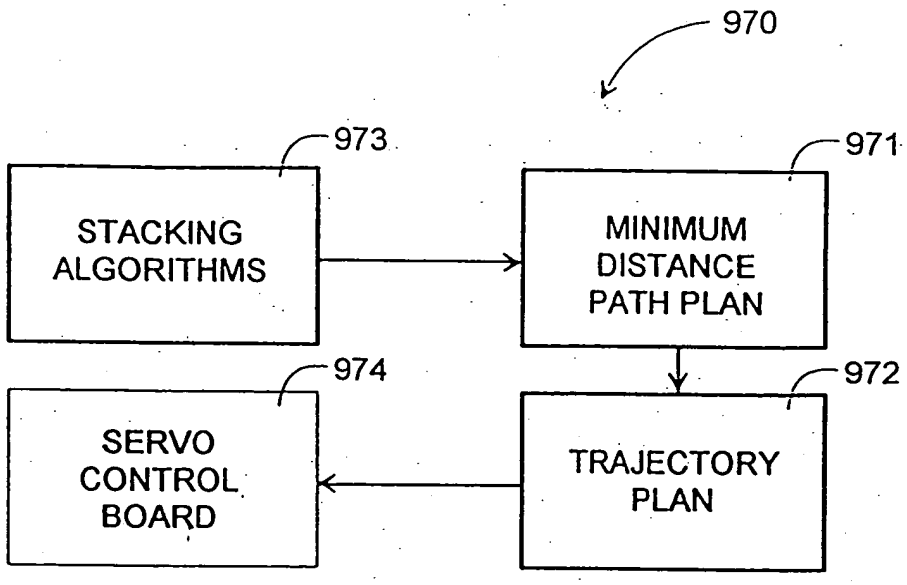

A
B
C
D
E
F
G
e
q
NOMINAL DISTANCE TO CENTER OF PACKAGE "F"
ACTUAL DISTANCE TO CENTER OF PACKAGE "F"
INDIVIDUAL PACKAGE ERROR "q" FOR PACKAGE "F"

FIG. 96



SOFTWARE MODULES INTERACTION

FIG. 97

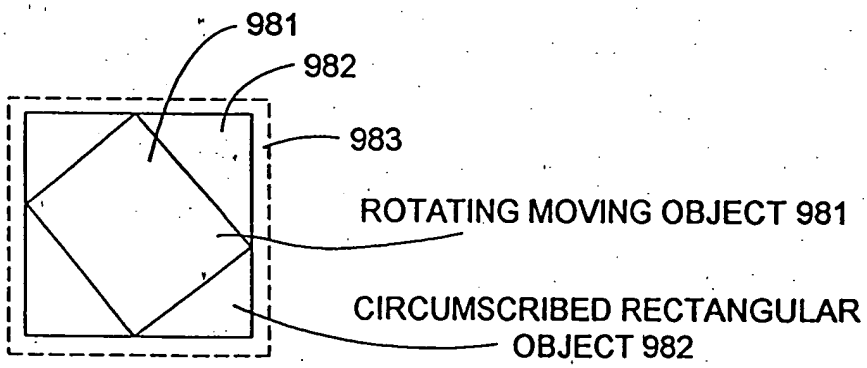


FIG. 98

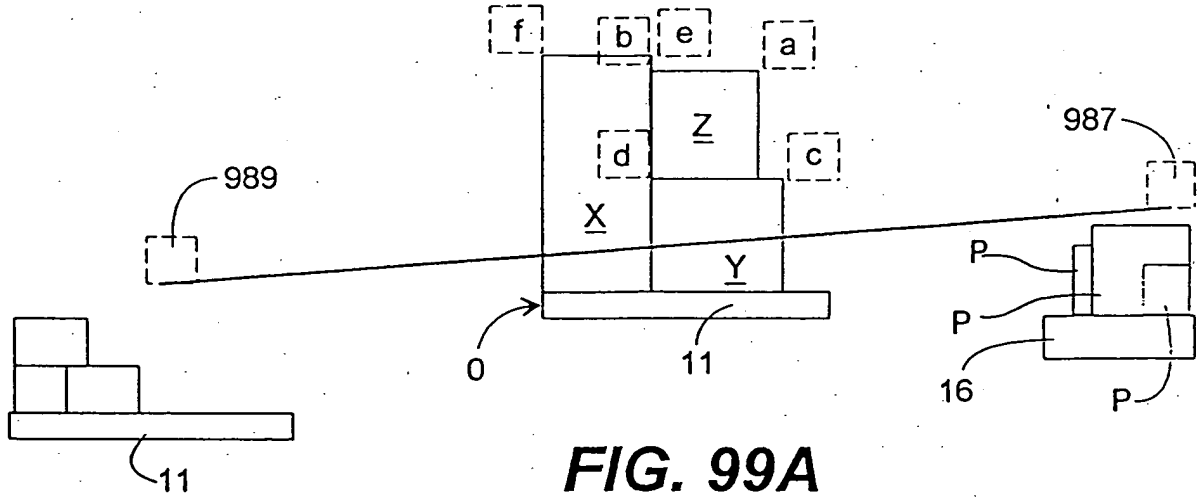


FIG. 99A

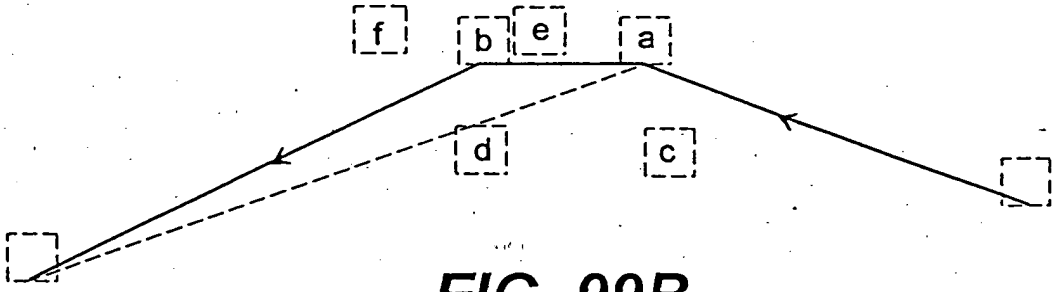


FIG. 99B

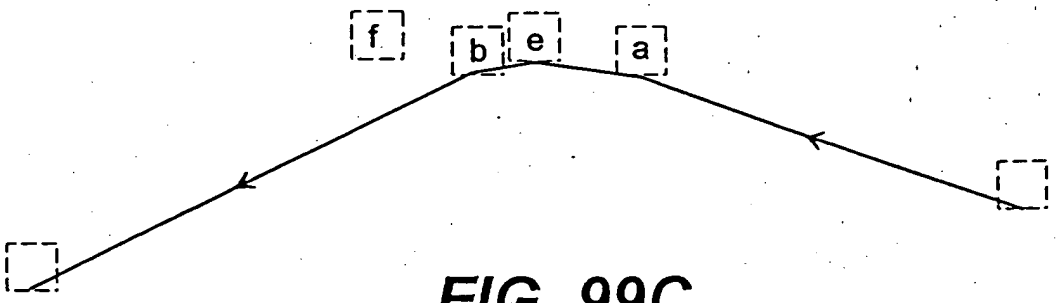


FIG. 99C

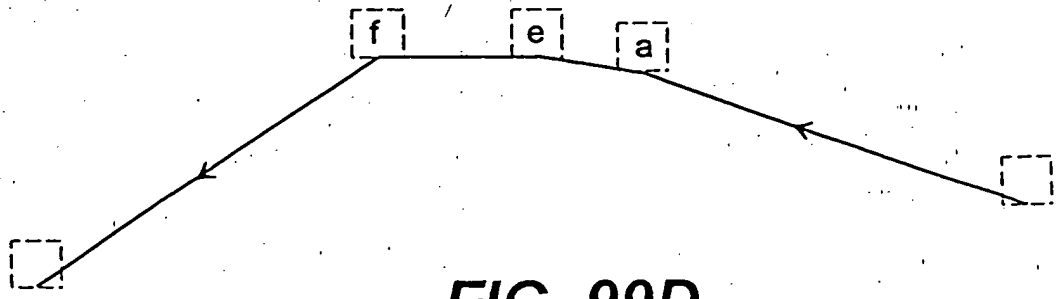
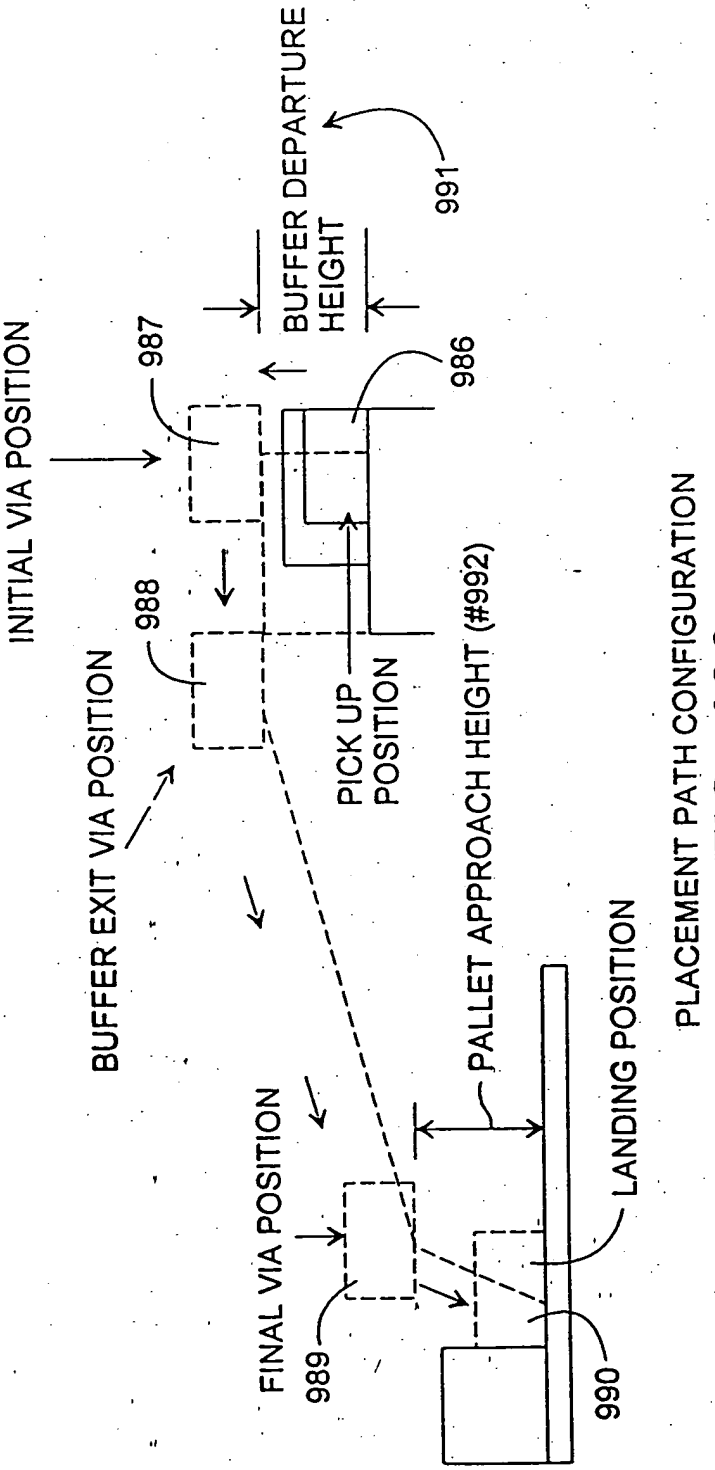


FIG. 99D



PLACEMENT PATH CONFIGURATION

FIG. 100

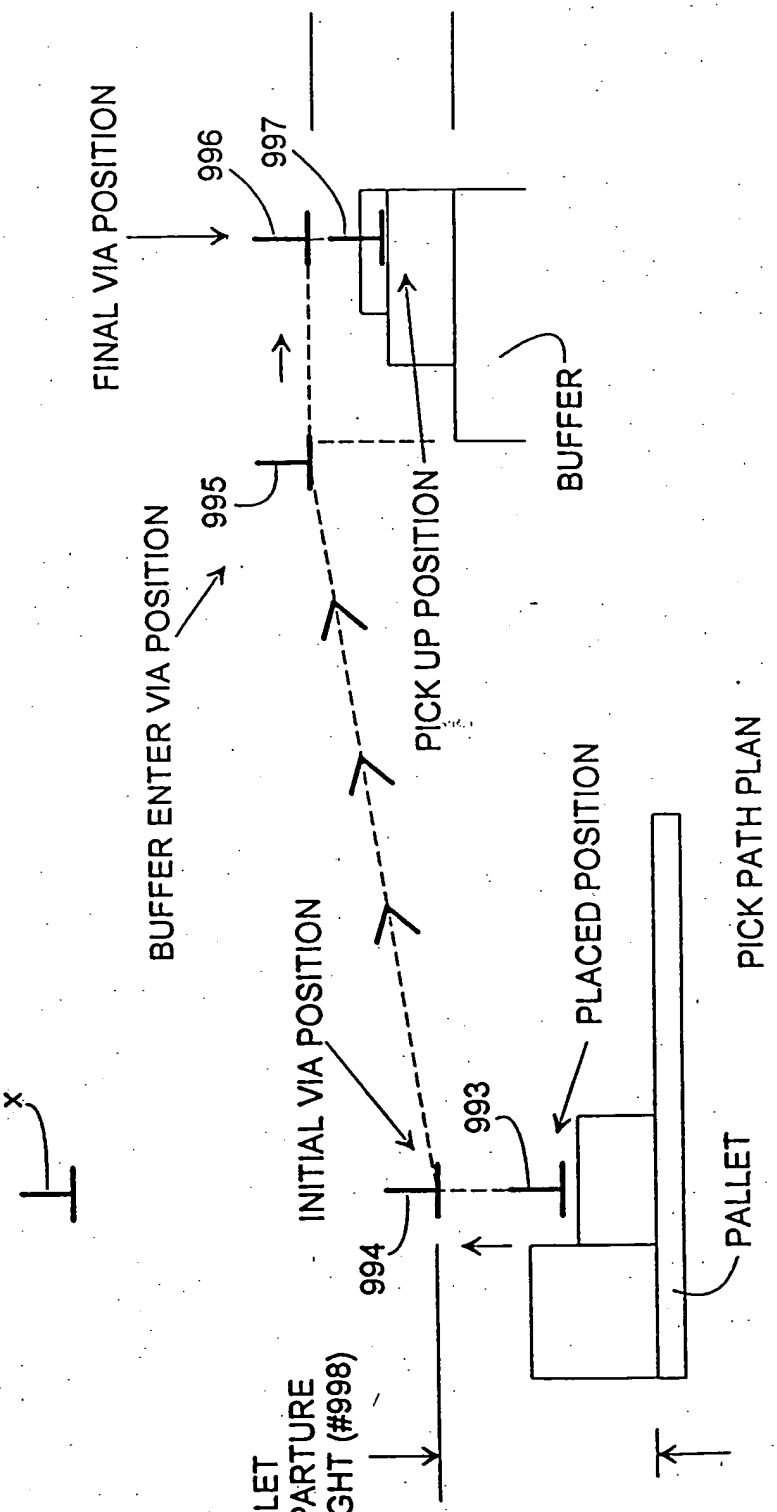
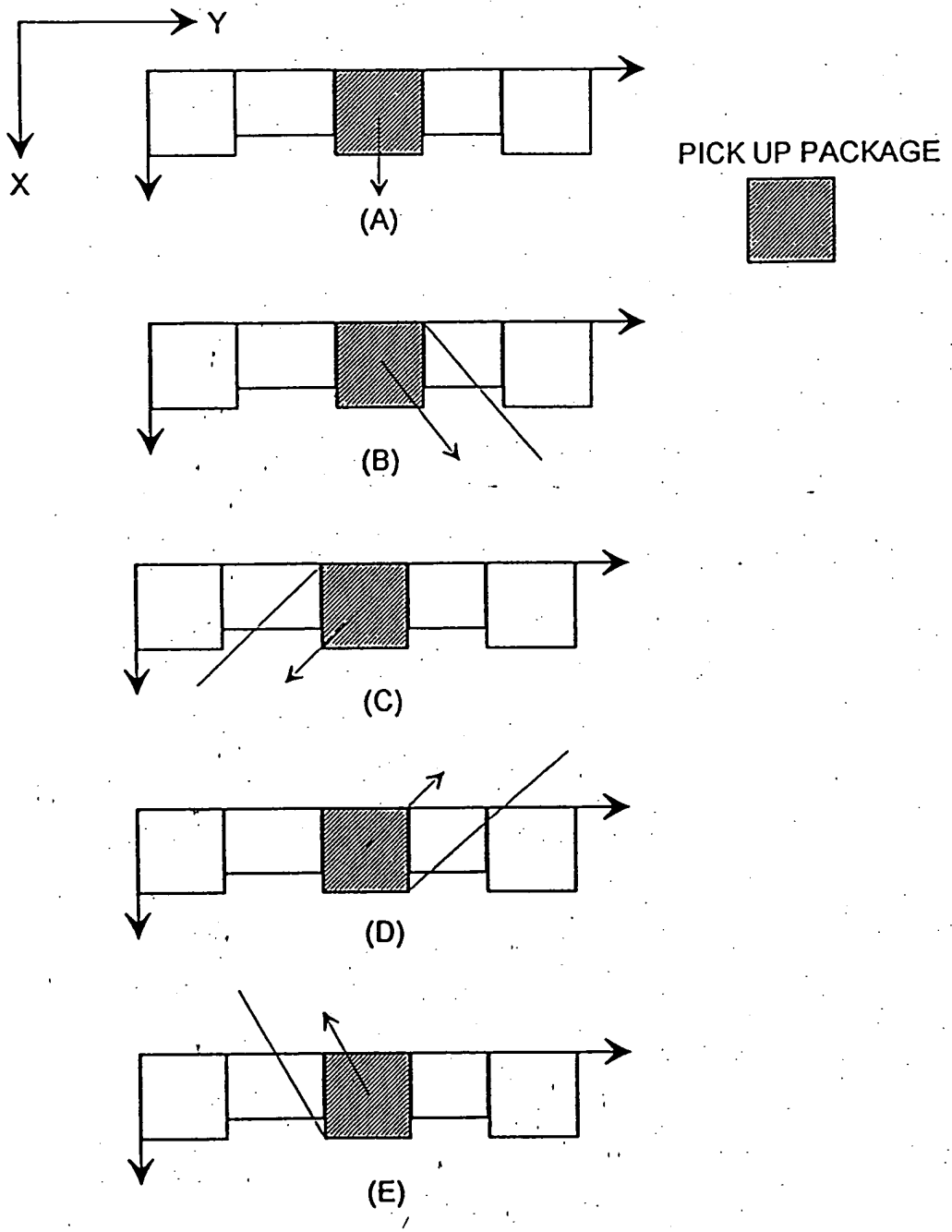

FINAL VIA POSITION
996
997
BUFFER ENTER VIA POSITION
995
PICK UP POSITION
BUFFER
INITIAL VIA POSITION
993
PLACED POSITION
994
PALLET
PICK PATH PLAN
PALLET DEPARTURE HEIGHT (#998)
x

FIG. 101



BUFFER LIFT HEIGHT COMPUTATION

FIG. 102

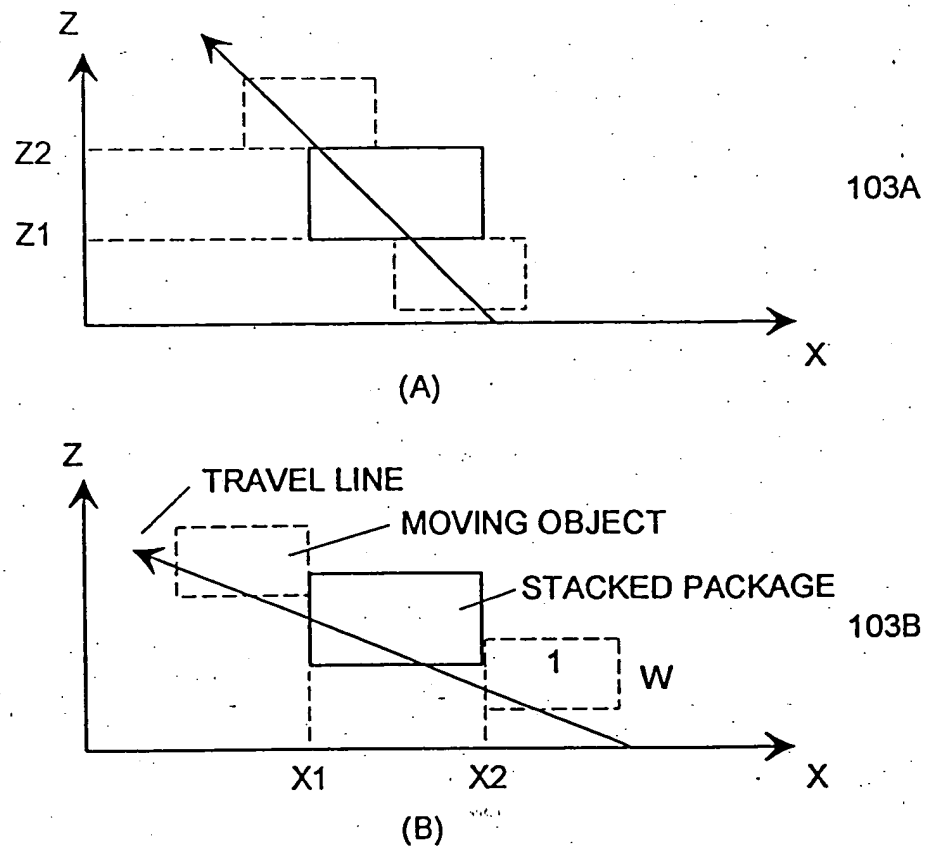
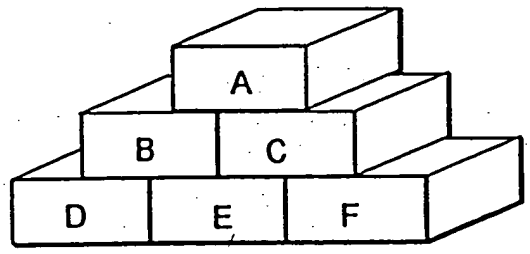
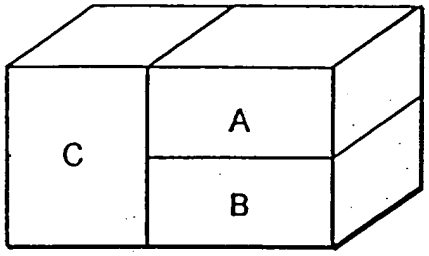


FIG. 103



RE: WEIGHT PASSING FROM LAYER TO LAYER

FIG. 104



RE: WEIGHT PROPAGATION

FIG. 105

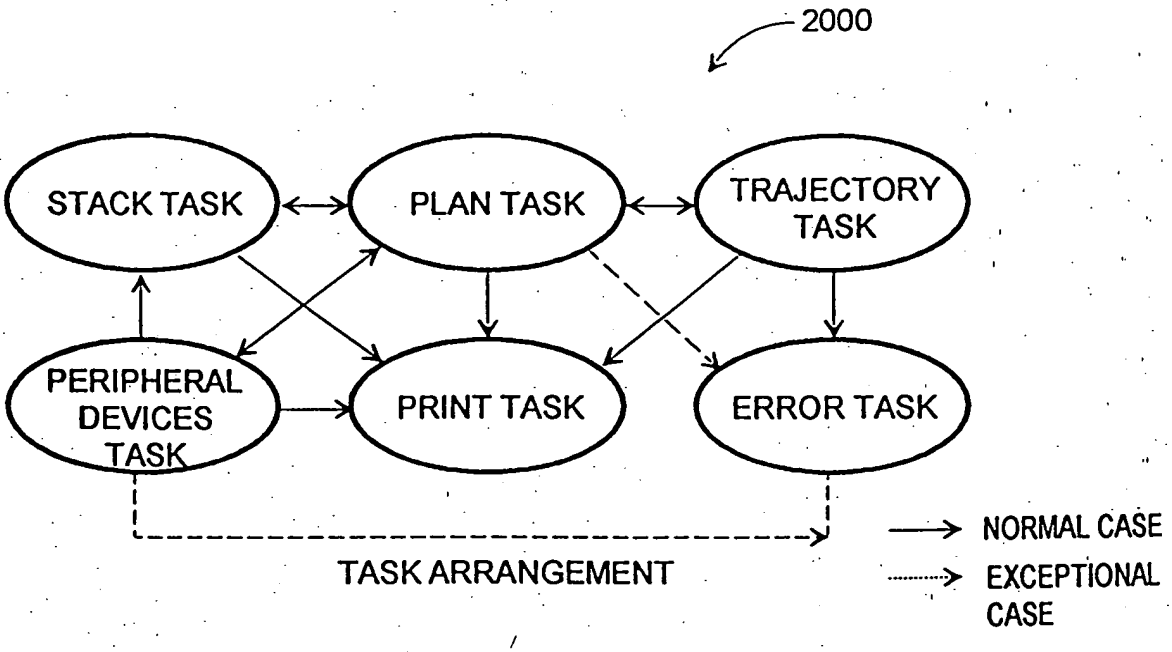
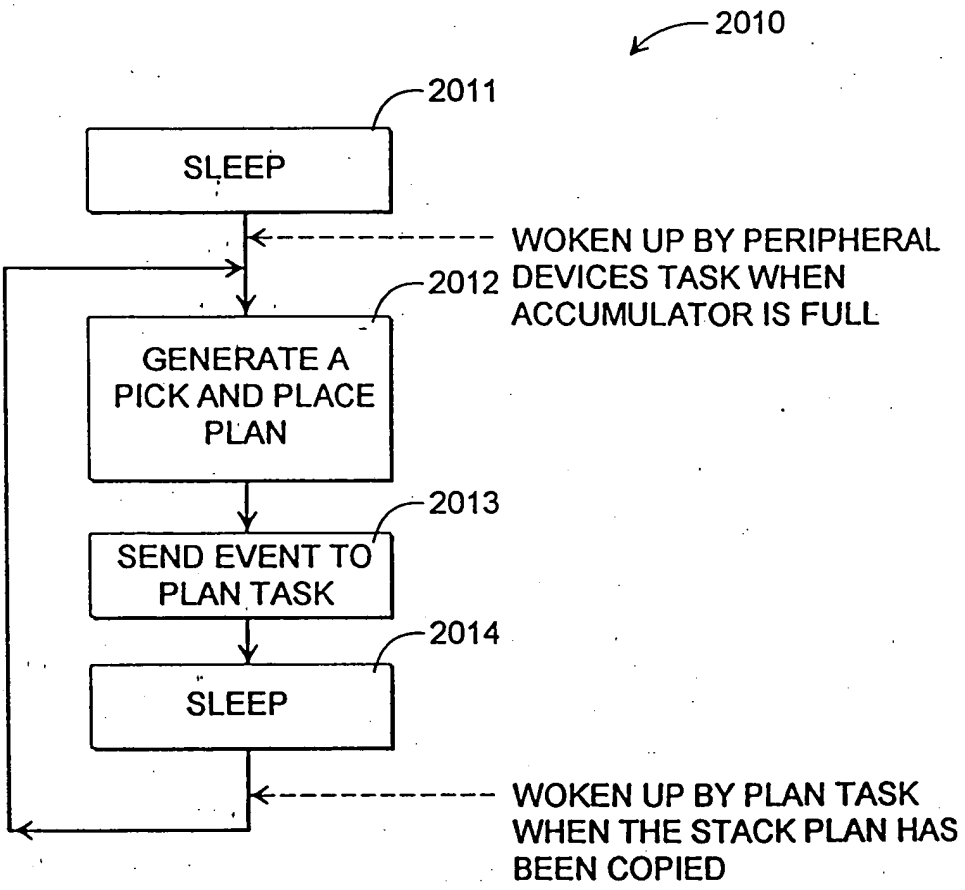
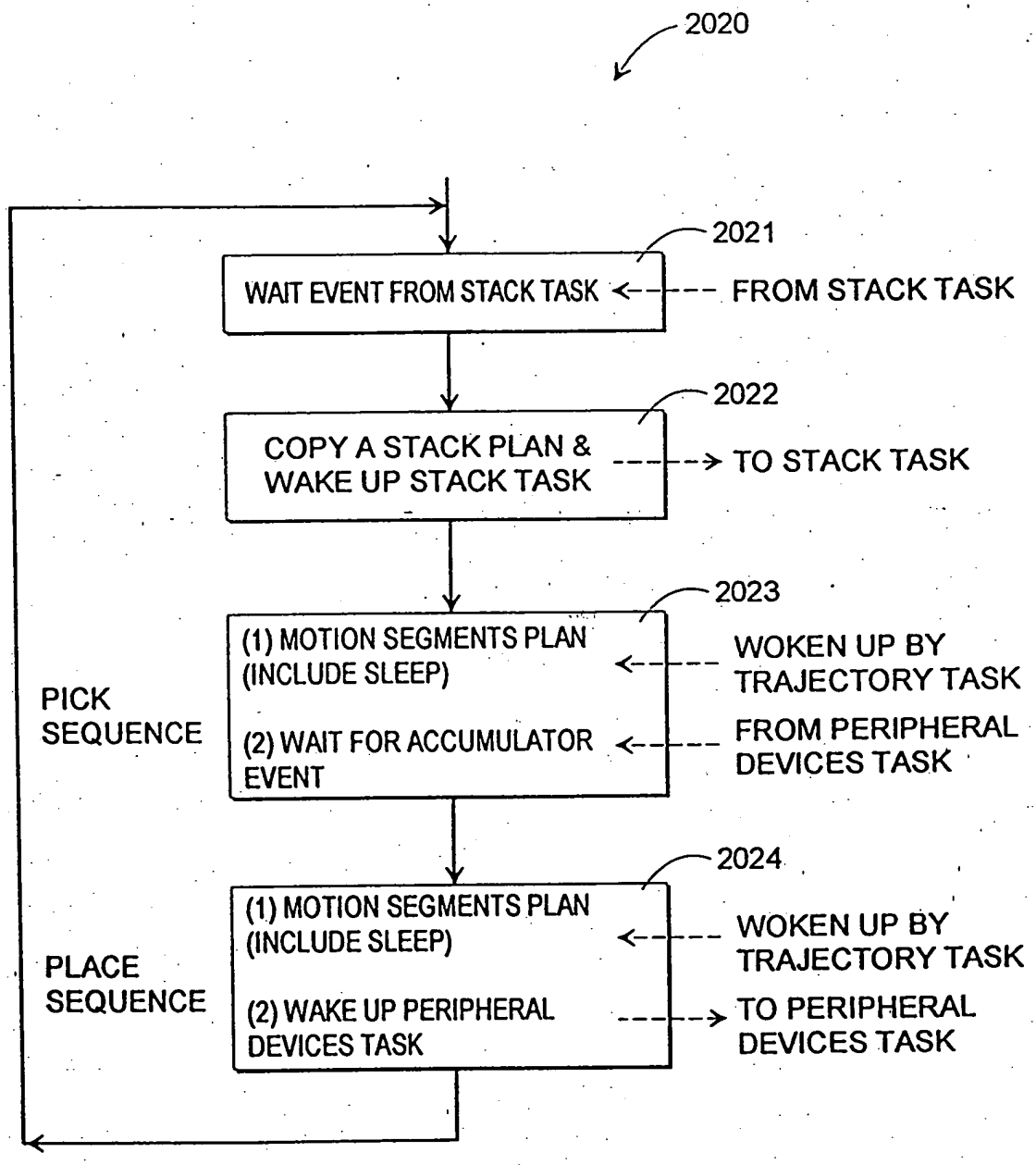


FIG. 106



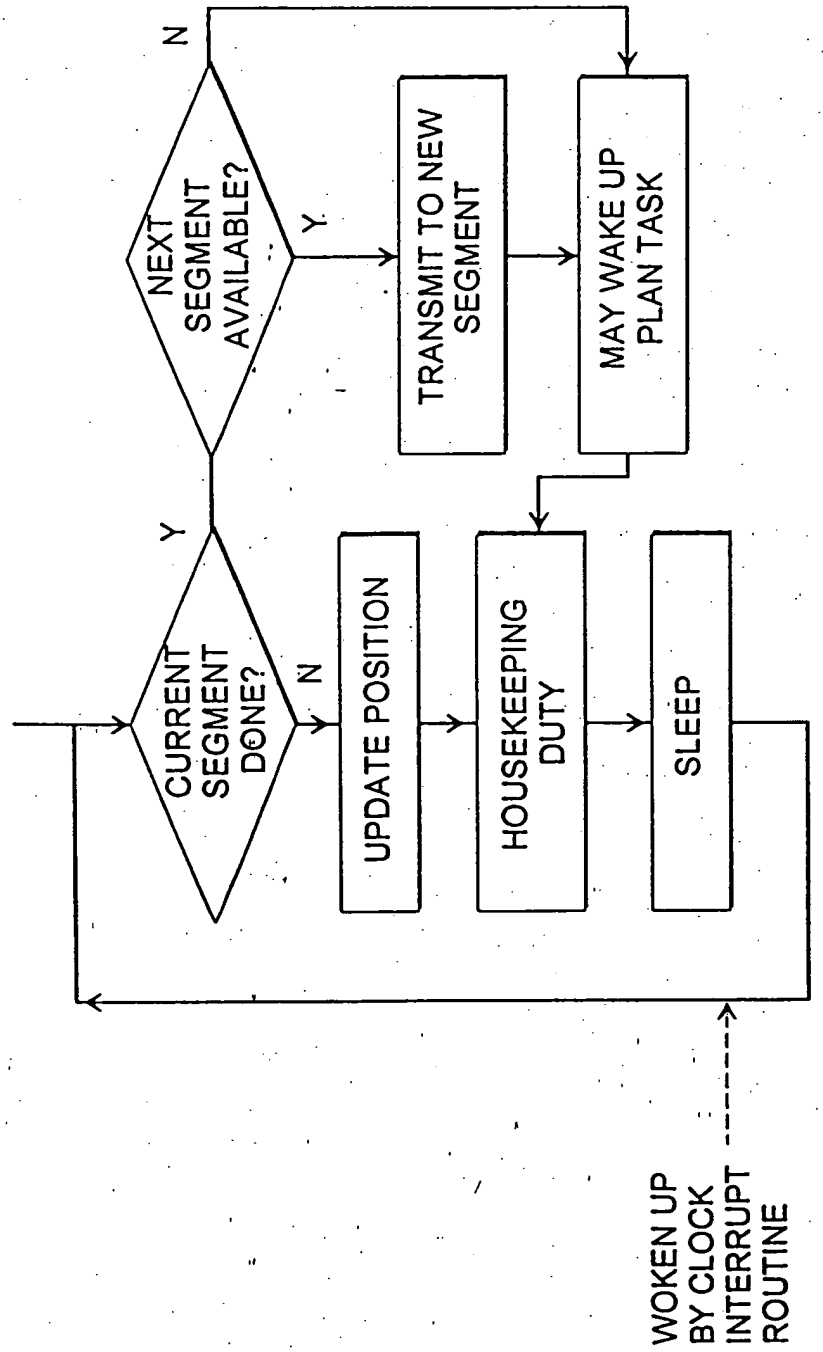
STACK TASK EXECUTION FLOW CHART

FIG. 107



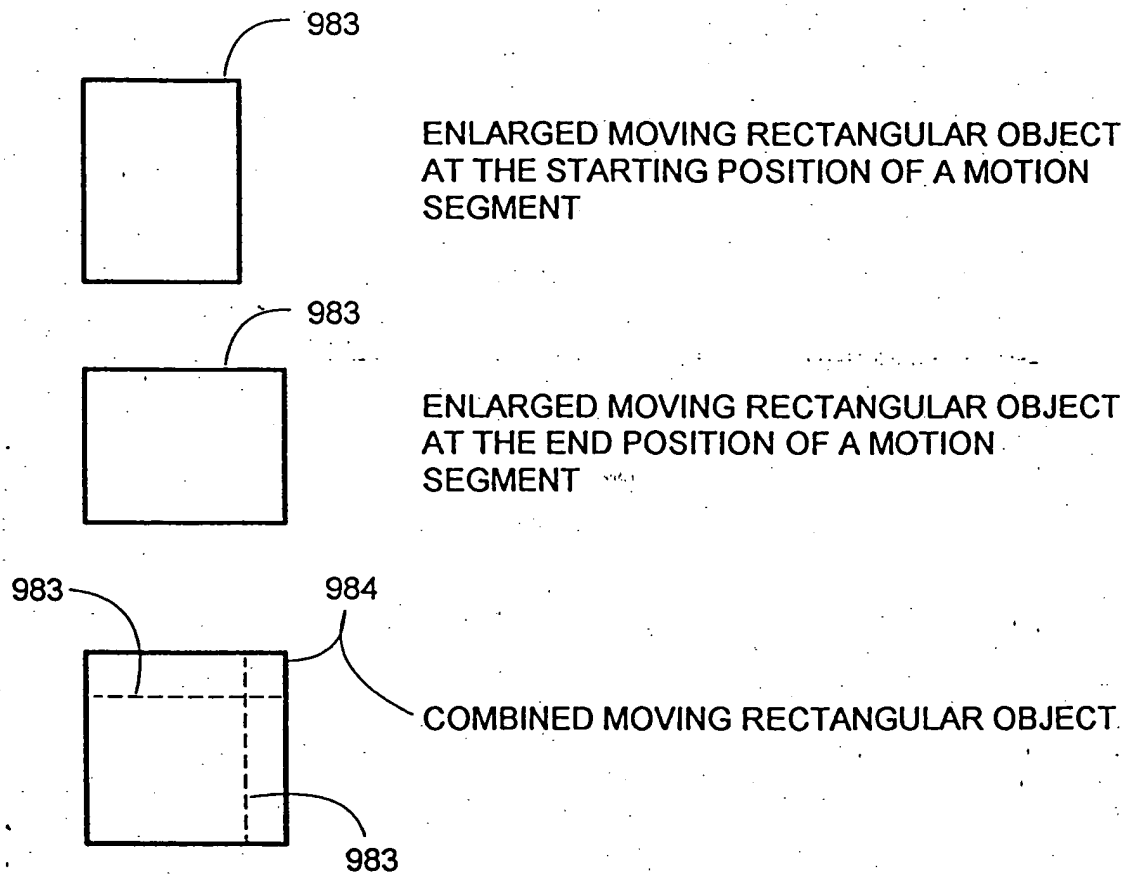
PLAN TASK EXECUTION FLOW CHART

FIG. 108



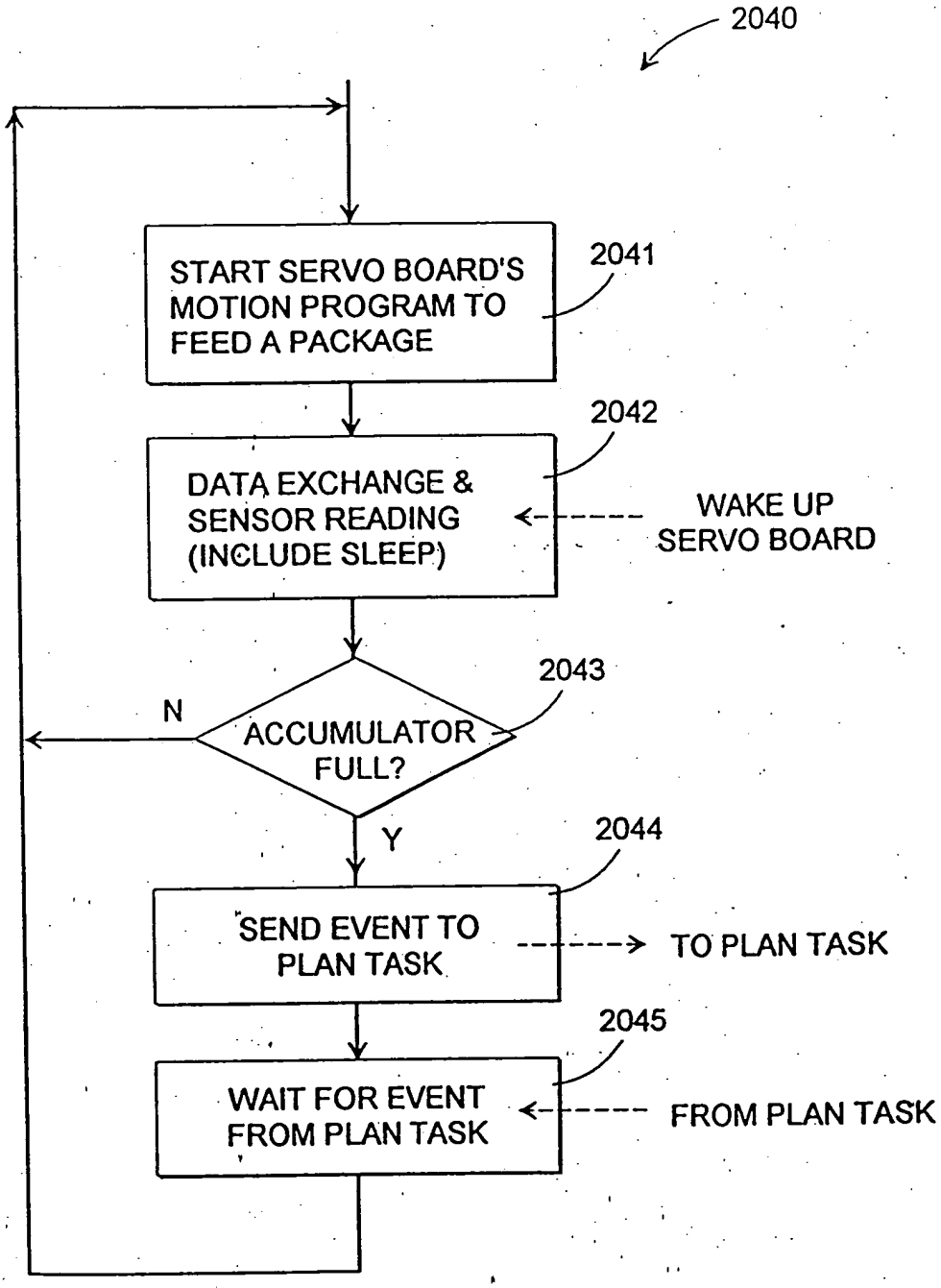
TRAJECTORY TASK EXECUTION FLOW CHART

FIG. 109



COMBINED MOVING RECTANGULAR OBJECT DEFINITION

FIG. 110



PERIPHERAL DEVICES TASK EXECUTION FLOW CHART

FIG. 111

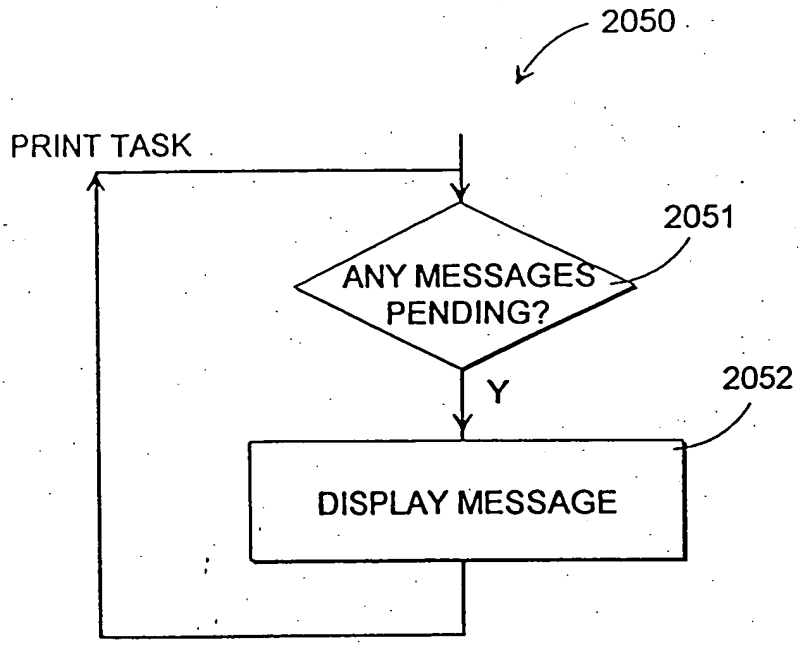


FIG. 112

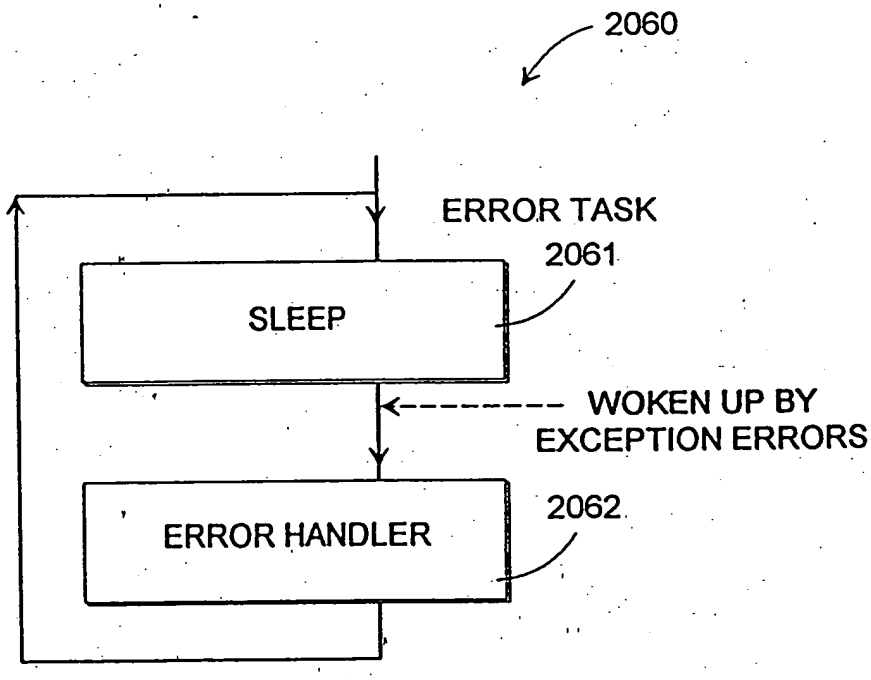


FIG. 113

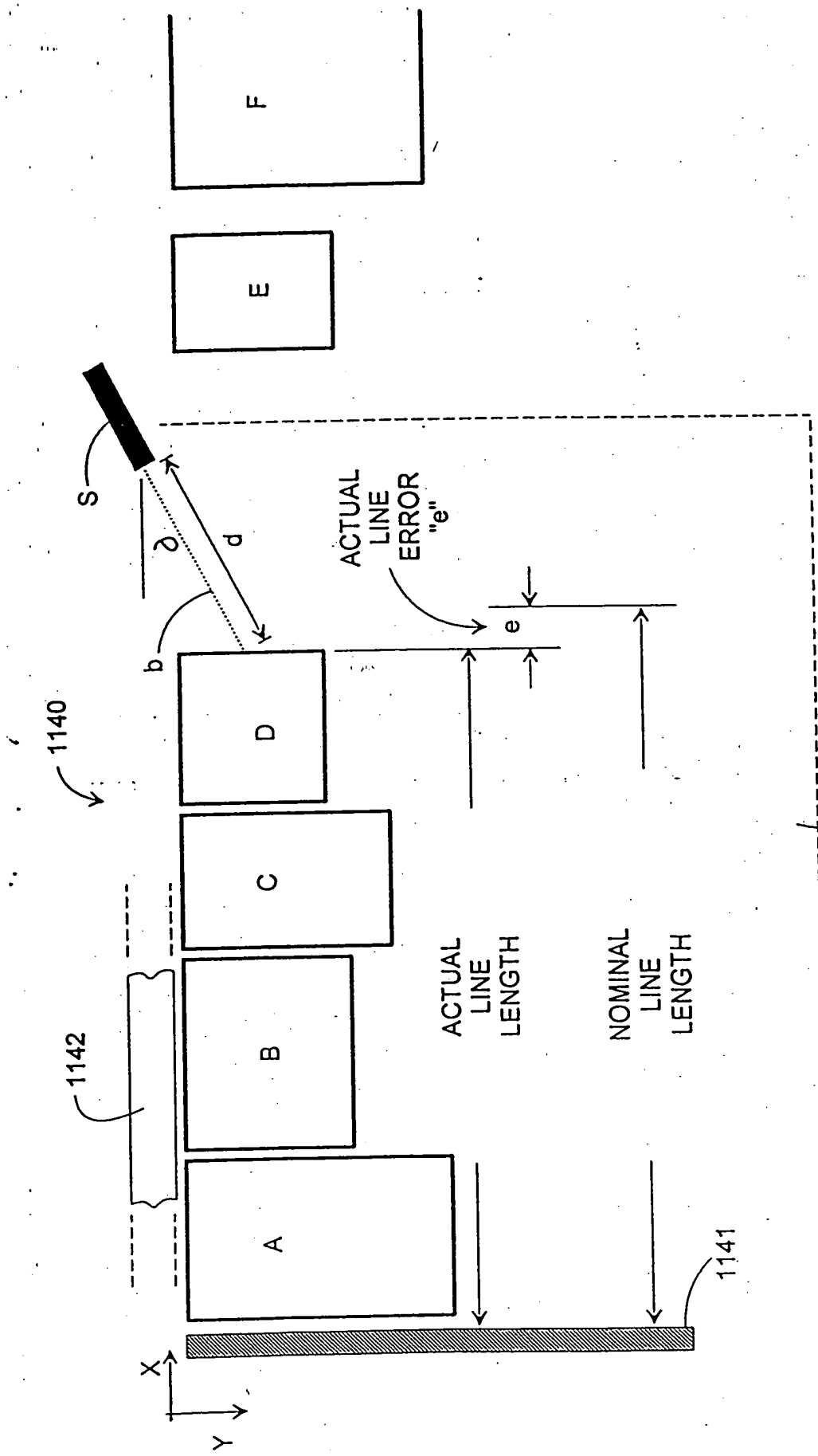

F
E
S
∂
d
b
ACTUAL LINE ERROR "e"
e
D
C
B
A
1140
1142
1141
ACTUAL LINE LENGTH
NOMINAL LINE LENGTH
ACCUMULATOR CONVEYOR
X
Y

FIG. 114

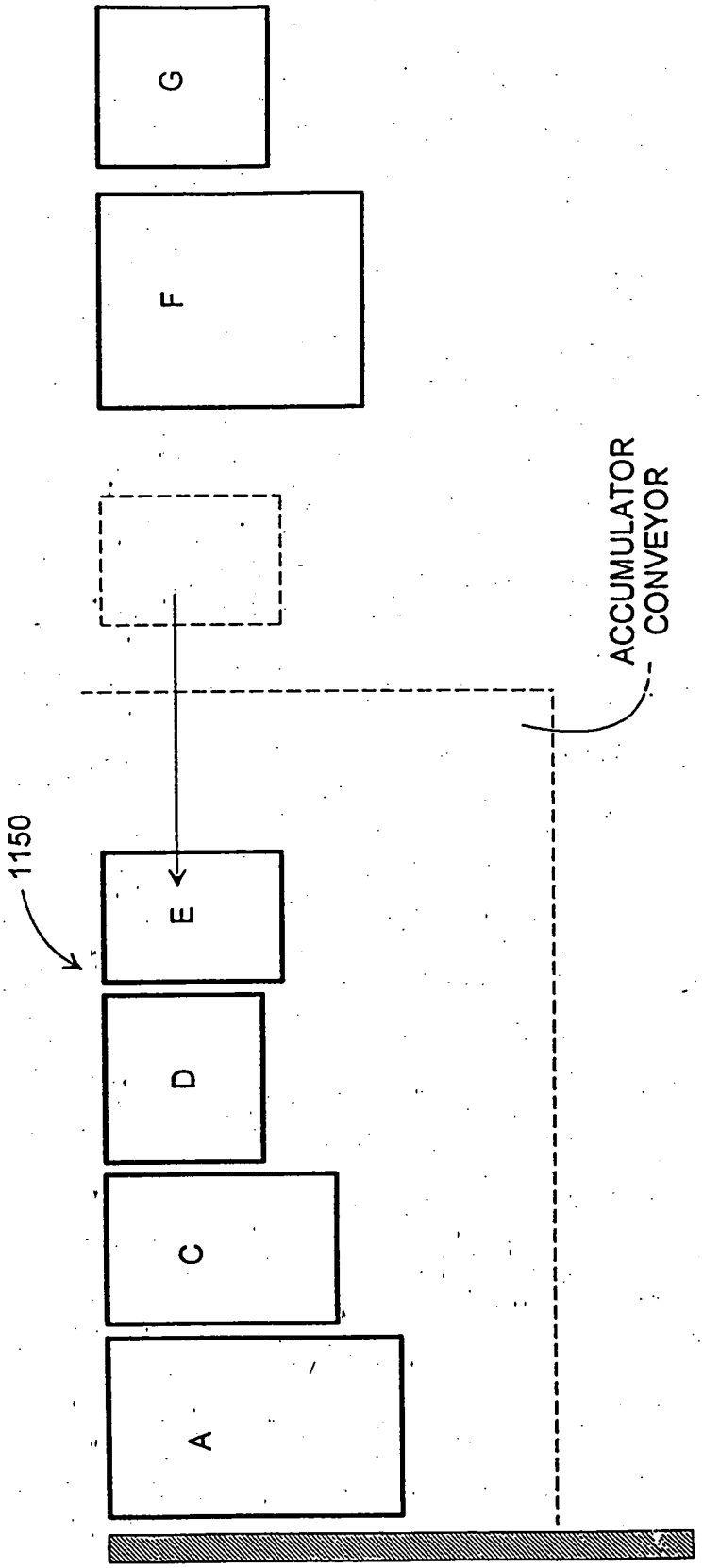


FIG. 115

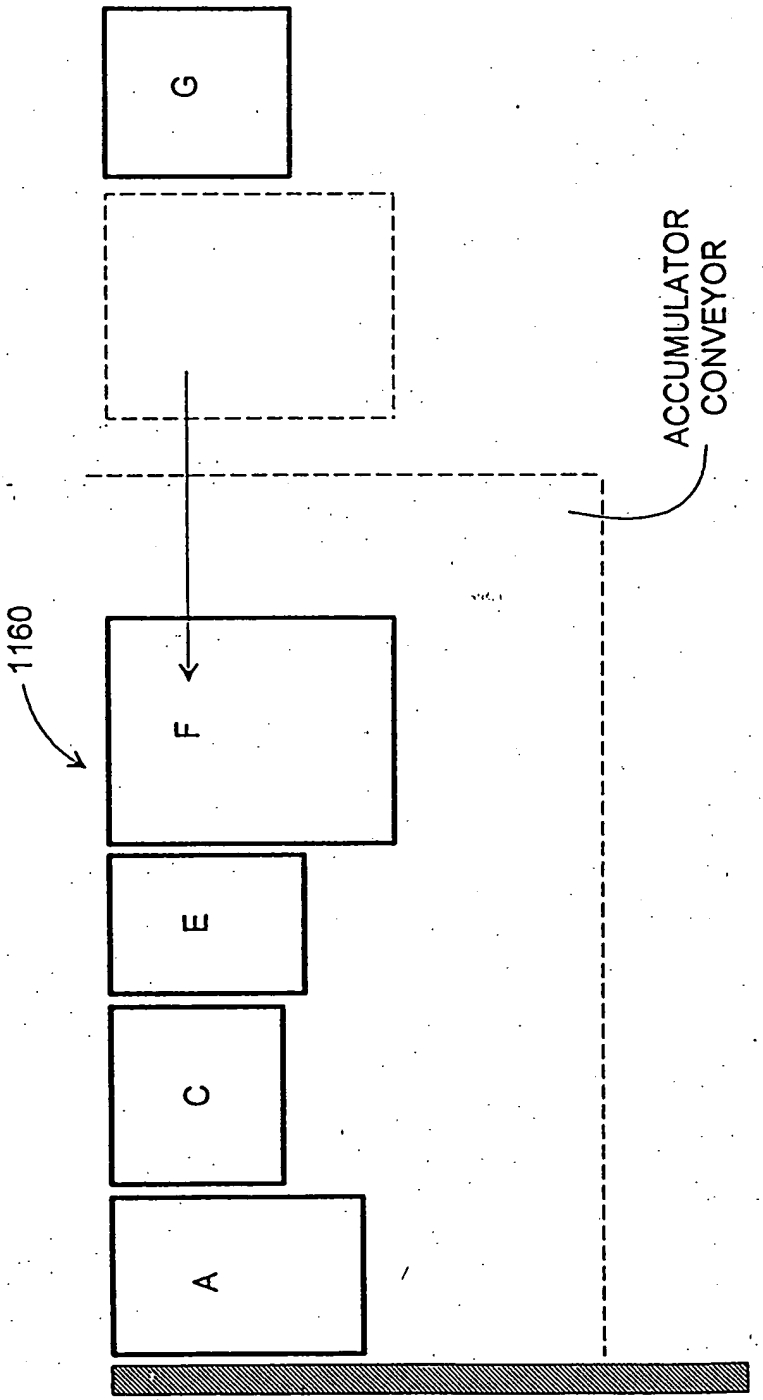


FIG. 116

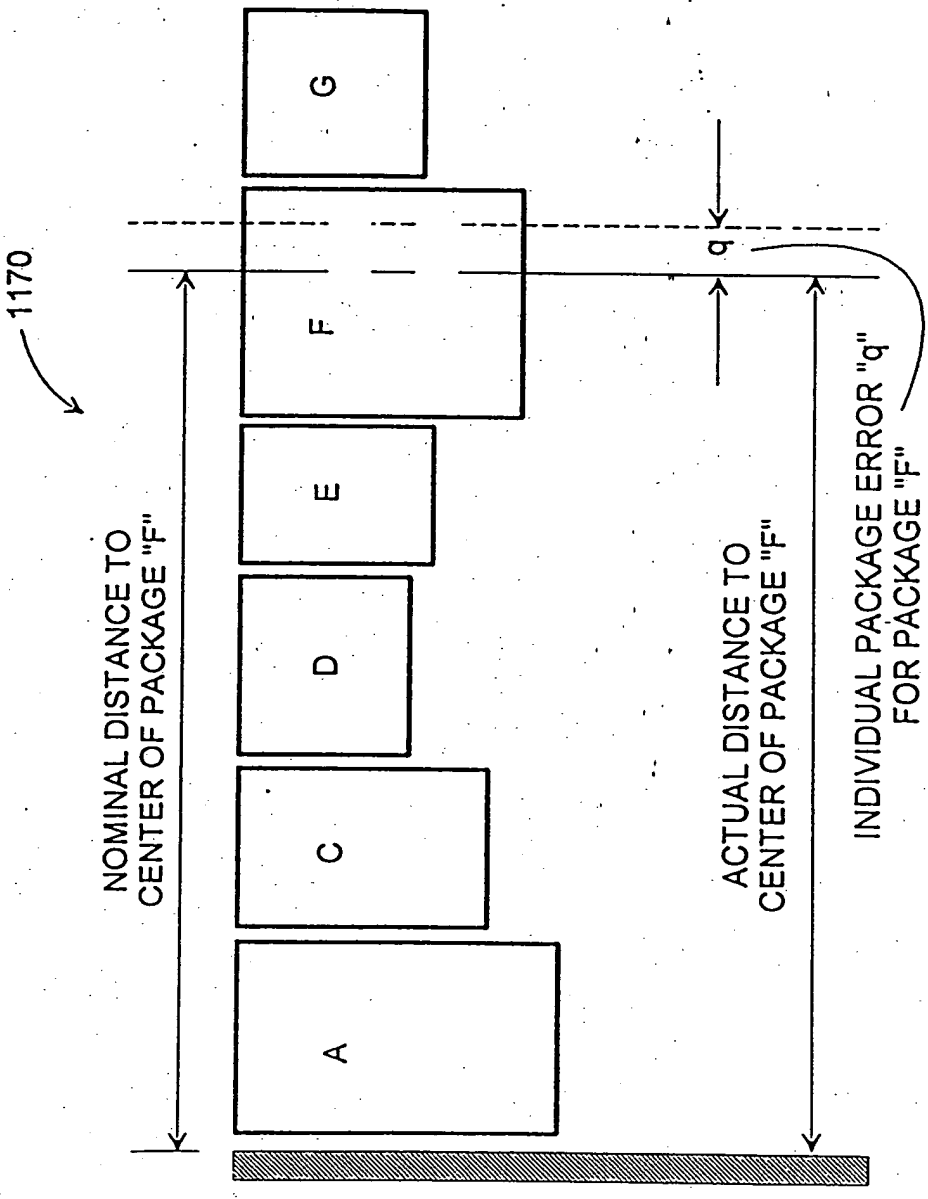

1170
A
C
D
E
F
G
q
NOMINAL DISTANCE TO CENTER OF PACKAGE "F"
ACTUAL DISTANCE TO CENTER OF PACKAGE "F"
INDIVIDUAL PACKAGE ERROR "q" FOR PACKAGE "F"

FIG. 117